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FIELD EVALUATION OF THE SITE CHARACTERIZATION AND ANALYSIS PENETROMETER SYSTEM AT PHILADELPHIA NAVAL SHIPYARD PHILADELPHIA, PENNSYLVANIA

by

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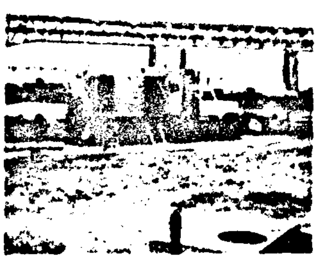

December 1992

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Philadelphia Naval Shipyard
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GEOTECHNICAL LABORATORY

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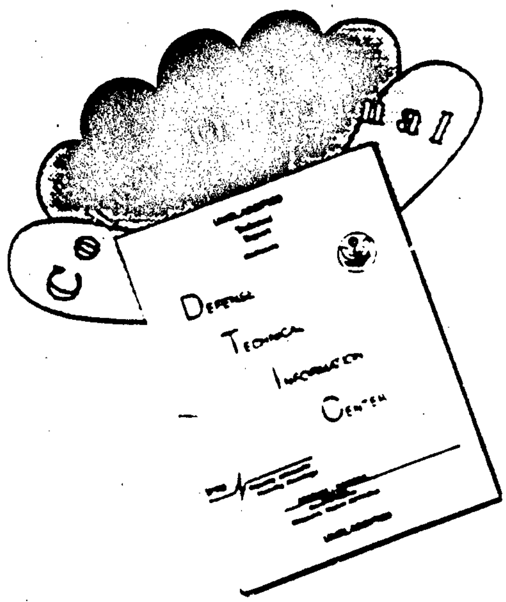

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13. ABSTRACT *(Maximum 200 words)*

This report documents the results of an investigation at the Philadelphia Naval Shipyard, Philadelphia, Pennsylvania. The site was investigated utilizing the Site Characterization and Analysis Penetrometer System, with a fiber optic fluorimeter sensor. This sensor allows the detection of hydrocarbon contaminants in the subsurface. A total of six sites were investigated at the base, at locations that were known or suspected to contain hydrocarbon contaminants. The sensor mounted in a conventional cone penetrometer was able to detect and characterize the contaminants in the vertical and horizontal directions. Of the six sites investigated, five were found to have contaminants. The concentrations at the various sites are reported herein.

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PREFACE

The Earthquake Engineering and Geosciences Division (EEGD), Geotechnical Laboratory (GL), Waterways Experiment Station (WES), was tasked by the Environmental, Safety, and Health Office of Philadelphia Naval Shipyard (PNSY) to undertake a demonstration/evaluation of the Site Characterization and Analysis Penetrometer System at various sites of PNSY. The operation was conducted as part of the U S Army Toxic and Hazardous Materials Agency (USATHAMA) Tri-services Research Project on the application of cone penetrometer-based technology for the detection and delineation of contaminated soils. Coordination with USATHAMA was provided by Mr. Wayne Sisk and Mr. Robert Bartell. The field demonstration/evaluation was conducted from 10 July to 24 July 91. The PNSY Project Officer for this work was Mr. Reid Parramore of the Environmental office.

The field work was conducted by Messrs. Michael K. Sharp, Richard S. Olsen, Karl F. Konecny, and Don Harris, EEGD, and Messrs. Jeff Powell and Cliff Grey, Instrumentation Services Division (ISD), WES.

Report preparation was done by Messrs. Michael K. Sharp, Richard S. Olsen, and Raju Kala, EEGD, and Jeff Powell, ISD.

The project was under the direct supervision of Mr. Joseph R. Curro, Jr., Chief, Engineering Geophysics Branch, Dr. A. G. Franklin, Chief, EEGD, and Dr. W. F. Marcuson III, Director, GL.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Leonard G. Hassell, EN.

CONTENTS

CONVERSION FACTOR, NON-SI TO SI (METRIC)
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
gallons	3.785412	cubic decimeters
inches	2.54	centimetres
miles (US statute)	1.609347	kilometres
pounds (mass)	0.4535924	kilograms
tons (2,000 pounds, mass)	907.1847	kilograms

FIELD EVALUATION OF THE SITE CHARACTERIZATION AND ANALYSIS

PENETROMETER SYSTEM AT

PHILADELPHIA NAVAL SHIPYARD, PHILADELPHIA, PA

PART I: INTRODUCTION

Background

1. The Earthquake Engineering and Geosciences Division was tasked by the Environmental, Safety, and Health Office of Philadelphia Naval Shipyard (PNSY) to undertake a demonstration of the Site Characterization and Analysis Penetrometer System (SCAPS) at various sites on PNSY where contaminated soil was known or suspected to be present. PNSY is located at the confluence of the Delaware and Schuylkill rivers (Figure 1) and serves as a support facility for certain Navy vessels. In this capacity, the facility maintains numerous amounts of petroleum and petroleum by-products. The sites investigated at PNSY involved areas where storage tanks were known or were suspected to have leaked.

2. A test plan was designed and coordinated with personnel of PNSY to investigate seven sites around the base. Investigation of the sites was conducted with sensors that can measure the strength properties of the soil, and the UV-excited fluorescence of soil surrounding the probe. Depth of investigation was limited to eighteen feet, as dictated by PNSY personnel, to maintain the integrity of an aquiclude overlying a shallow aquifer. The water table at the base ranged between a depth of five and ten feet.

Purpose

3. The primary objective of the field effort is to demonstrate and evaluate the equipment and procedures used in the penetrometer-based site investigation system (SCAPS), developed in a USATHAMA Triservices Research and

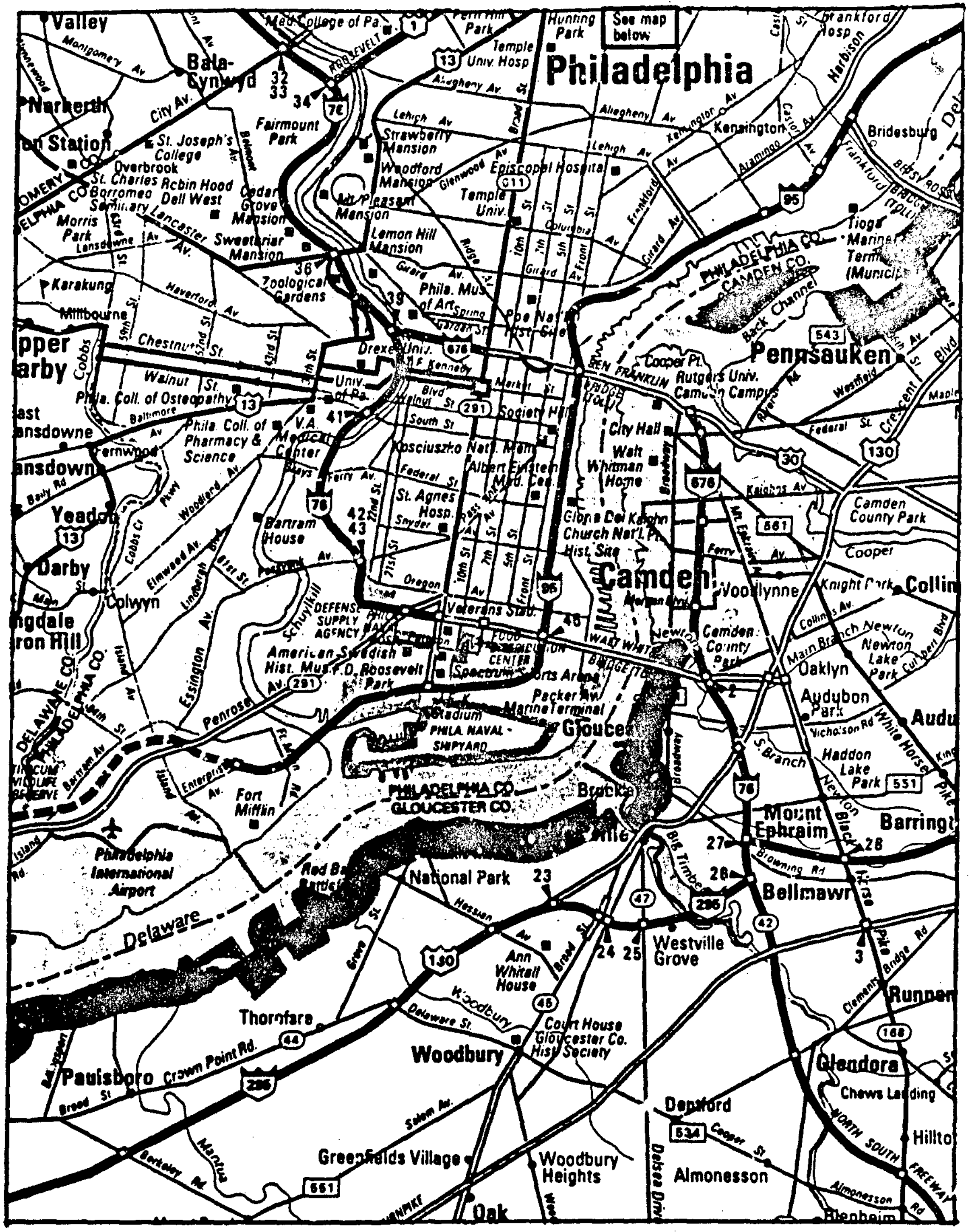


Figure 1. Location of Philadelphia Naval Shipyard.

Development Project. The field test included the evaluation of the topographic surveying system, the surface geophysical investigation, the penetrometer (with soil strength, and fluorometric measuring instruments), soil grouting equipment and data reduction (data visualization). As a secondary objective data were obtained that are available for site evaluation and remediation planning as needed. The objective was not a complete definition of the extent of shallow hydrocarbon contamination. Substantially more probes than conducted would have been required at most of the seven sites.

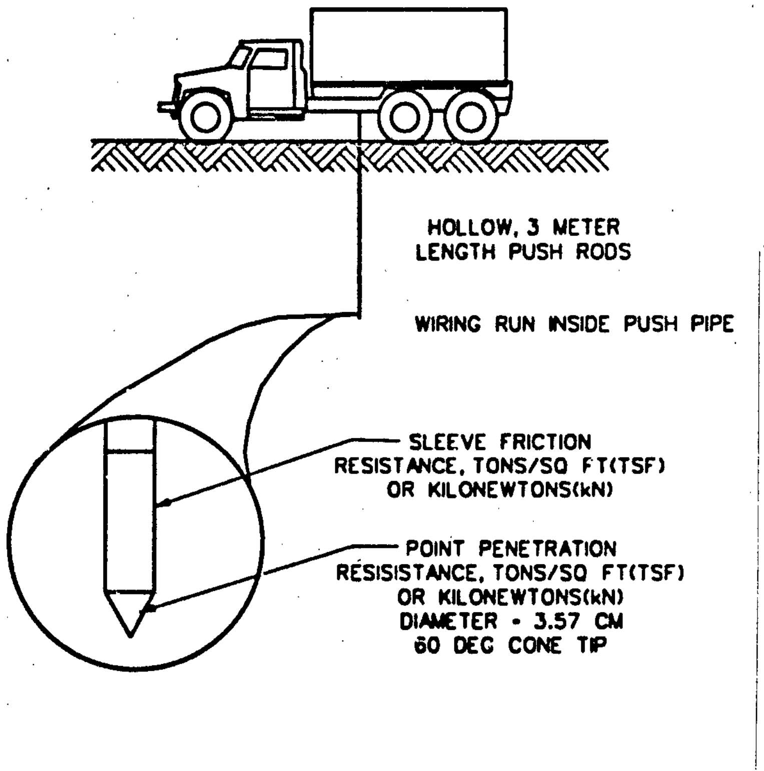
PART II: EXPERIMENTAL EQUIPMENT AND METHODS

General

4. The Site Characterization and Analysis Penetrometer System (SCAPS), includes a suite of surface geophysical equipment, survey and mapping equipment, special penetrometers with sensors for contaminant detection, and soil and pore fluid penetrometer samplers. The experimental penetrometer system is mounted in a specially-engineered truck (Figure 2) designed with protected work spaces to allow access to toxic and hazardous sites while minimizing exposure of the work crew. The SCAPS "screening" penetrometers are equipped with sensors that can determine certain physical and chemical characteristics of the soil as the penetrometer tip is forced through the soil. The SCAPS includes sensors that can determine the strength, electrical resistivity, and spectral properties, in this case the fluorescence, of soils. All sensors read out in real time, and a computer-based data collection and analysis system permits a display and partial interpretation of data in the instrument compartment on the penetrometer truck. The data analysis system also allows processing of various types of surface geophysical and mapping data collected on site, and integration of data into a unified data base. Fluid and soil samples can be collected using devices such as the commercial "stab type" groundwater and soil samplers that are designed for use with penetrometers. The SCAPS system is also equipped to seal each penetrometer hole with grout as the geotechnical investigation proceeds across a site. The SCAPS unit is built so that surfaces and compartments exposed to waste can be thoroughly and completely decontaminated. Post processing of the data to provide a 3-D visualization of site conditions is presently done with a computer work station that can be used at WES or brought to the installation. SCAPS is designed to save time and costs and to minimize exposure of the crew while sensor data or samples are collected. Penetrometer units available commercially do not have this combination of capabilities.

Site Mapping Methods

5. The location of penetrometer push points and the layout of the



<u>BASIC CONFIGURATION OF SCAPS TRUCK</u>

MOUNTED ON ALL WHEEL DRIVE TRUCK (MODIFIED M814 MILITARY CHASSIS)
HYDRAULICALLY POWERED PUSH APPARATUS 178-kN PUSH
WEIGHT APPROXIMATELY 21,000 KG
COMPUTER AIDED DATA ACQUISITION
MEASUREMENTS OF PENETRATION RESISTANCE
AT 1-INCH (2.5 CM) INTERVALS
ENCLOSED AIR-CONDITIONED WORKSPACE

Figure 2. Experimental penetrometer system and configuration.

geophysical survey stations is done using a total station electronic distance measuring system (EDM). Typical errors involved in the EDM survey were less than 10 cm per km (0.05 ft. per mi.). The survey for each site was tied to a local feature (fire hydrant, light pole, etc.) which was later located on a facility map and used to extract the northing, easting, and elevation information. Preliminary site maps were prepared from survey data using the computers in the SCAPS truck. The final site maps were generated at the WES.

Geophysical Investigation Methods

6. Geophysical site surveys were undertaken primarily to determine if there was metallic debris in the area where the penetrometer unit would be operating. Magnetic susceptibility was measured with the Geonics EM-31 Terrain Conductivity System (Geonics Inc., Mississauga, Ontario, Canada) operating in the in-phase mode. Geophysical investigations were severely hampered due to the intense amount of metal (buildings, ships, cranes, docks, etc.) in the area. The basis of each push, in terms of being safe from puncturing some metallic object, was determined from utility maps and knowledge of the area by PNSY personnel.

Sampling Procedures and Analytical Methods

7. No sampling of soils or fluids were performed at the PNSY. Sampling had been done by the PNSY prior to arrival of the SCAPS system. Laboratory results of total oil and grease from the collected soil samples were made available to WES personnel.

Grouting Methods

8. The SCAPS unit is equipped to seal the penetrometer holes using either a liquid (chemical) grout or conventional Portland cement-based grout. The chemical grout system is designed to inject a two-component grout through tubes running down the center of the penetrometer rod and seal the penetrometer hole as the rod is withdrawn. The system uses two high-pressure, positive-displacement pumps feeding into a pressure/volume regulating system

that can control the amount of each component dispensed. The chemical grout injection system can handle acrylate, urethane or silicate grouts. The SCAPS equipment also includes a conventional cement/bentonite grout mixer and a low-pressure progressive cavity pump for tremie grouting of penetrometer holes. At PNSY cement/bentonite grout was used. The grout was mixed in small batches of 20 to 50 liters (approximately 5 to 15 gallons) and was dispensed directly into the open penetrometer holes or through a tremie tube placed in the hole after the penetrometer rod was withdrawn.

Site Characterization Methods

9. The major component of the SCAPS system is a 20-ton, all-wheel-drive penetrometer truck that was designed specifically for operations at hazardous waste sites, an overall view of the system is shown in Figure 3. The truck carries a hydraulic power unit and controls to operate the push apparatus, a power takeoff driven 25-kw generator, dual air conditioning units, separated push and data acquisition work spaces, a shock-isolated floor for the penetrometer instrumentation, easily decontaminated stainless steel van body, and other personnel protection features. A specially designed trailer is used to carry the grouting pumps, water tank, and a closed-loop steam cleaner to clean the penetrometer rods and tools as they are withdrawn from the soil.

10. A specially designed moveable cone penetrometer platform (Figure 4) was prepared for use at the PNSY in anticipation of the need to perform penetrations at locations between closely spaced buildings where maneuvering and size limitations would prevent truck operations. The platform contains a hydraulic power unit and controls to operate the push apparatus. The platform measures 8 ft by 12 ft and weighs approximately 6 tons. Additional weights can be added to the platform to act as counterweights during pushes.

11. The electronics package includes WES-designed and built signal-conditioning hardware and test equipment capable of providing on-site calibrations of contaminant detectors and load cells used to make penetration resistance measurements. Data acquisition and initial data processing are carried out with an on-board computer with a matching computer used for data management

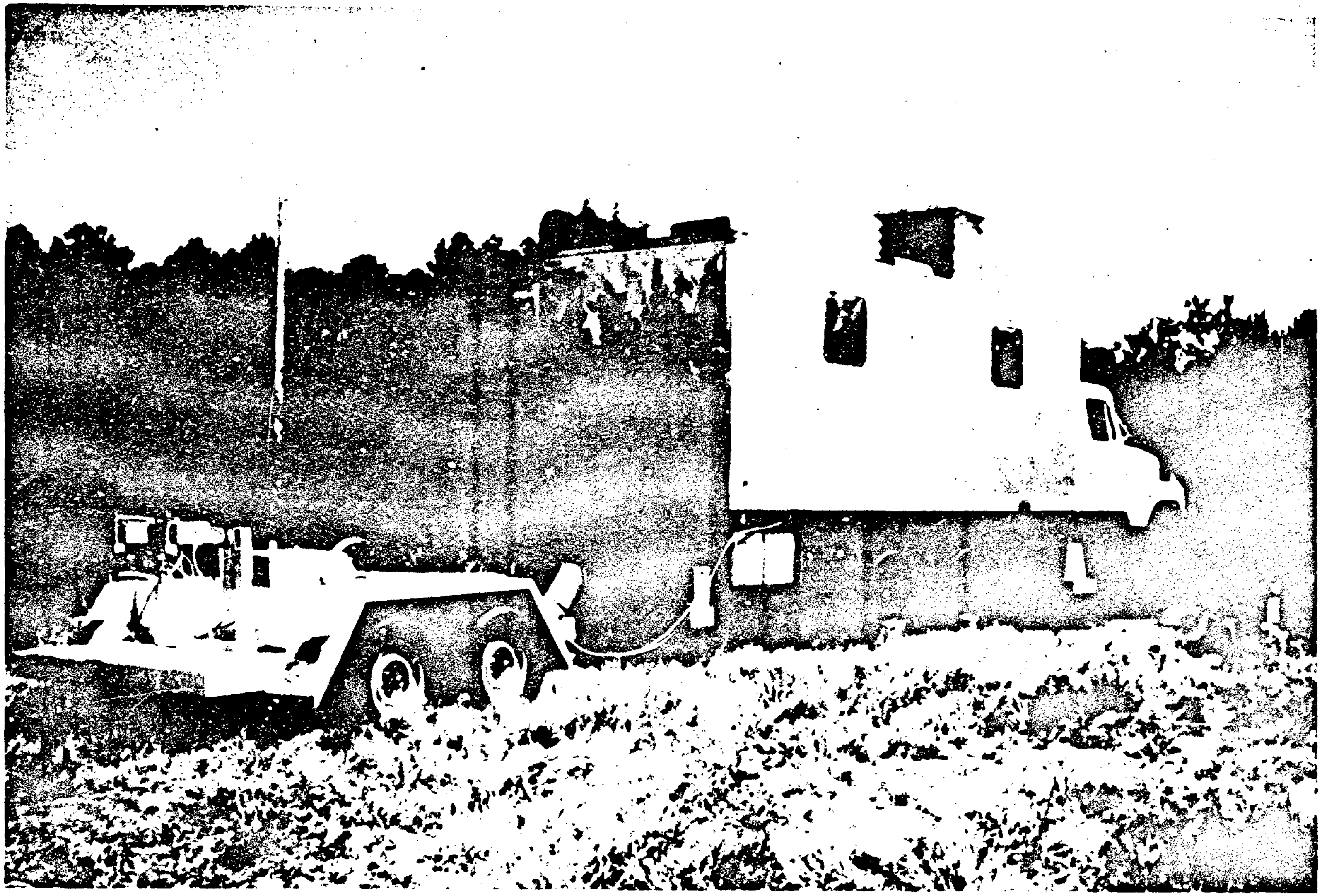


Figure 3. Photograph of penetrometer truck and grouting trailer.

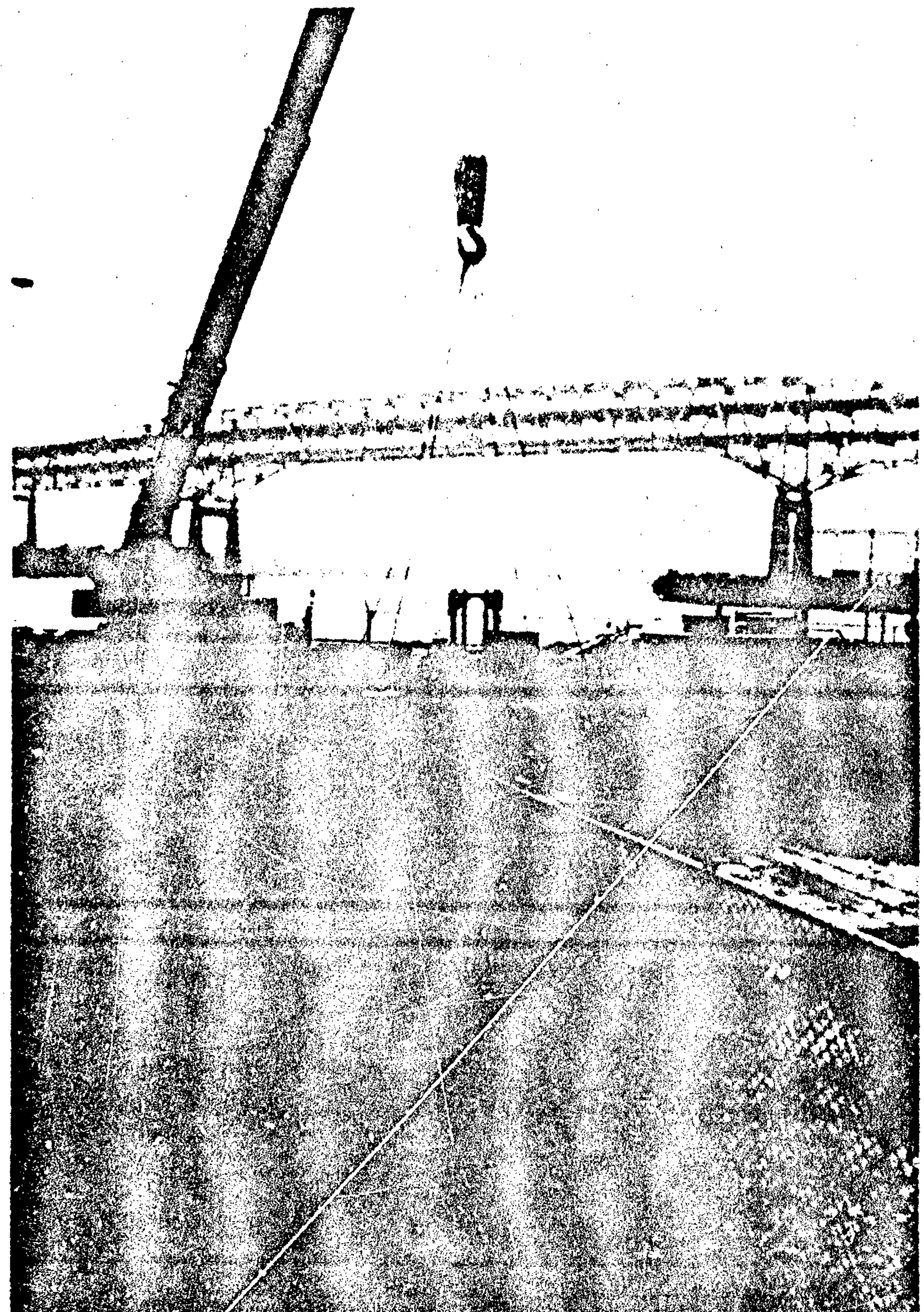


Figure 4. Photograph of specially designed portable penetrometer platform.

and file integration. The second computer affords redundancy in the event of a computer failure. A view of the data collection compartment of the truck is shown in Figure 5.

Soil Strength and Type Determination Methods

12. A sectional view of a penetrometer equipped to measure soil strength is shown in Figure 6. The point load cell is loaded in compression as the cone tip is advanced. The friction sleeve load cell is in the form of a hollow cylinder which is split along its cylindrical axis and strain gauged on the inside surface of each half shell. The cell surrounds the tip load cell and is also loaded in compression when soil friction acts on the friction sleeve which jackets the front of the probe. The design employed in this soil strength unit allows the tip penetration resistance and sleeve friction measurements to be made independently and continuously.

13. Two calibration procedures are used with the cone employed in this investigation so that separate calibration curves can be developed for the two load cells. The point resistance load cell is calibrated by cycling the load from zero load to approximately 7272 Kgf (equivalent to 16,000 psi) and back to zero load several times. The cell is then loaded to selected load increments and back to zero. The load cell output is read for each load increment applied and the zero load condition at the beginning and end of each loading increment. The load increments are increased until the compressive force reaches the maximum capacity of the cell. The friction sleeve load cell is calibrated in a similar way. Figures 7 and 8 show typical calibration curves obtained for a strain-gaged penetrometer instrument. Each load cell is calibrated independently but the output of each cell is measured as the calibration proceeds so that any influence of one cell on the output of the other can be determined. Typically neither cell shows any influence on the other. Calibration test responses are generally within 0.5% of the applied load. Load cell calibrations can be done in the field, but are generally completed prior to field deployment.

14. Techniques for using the soil strength measurements (cone tip

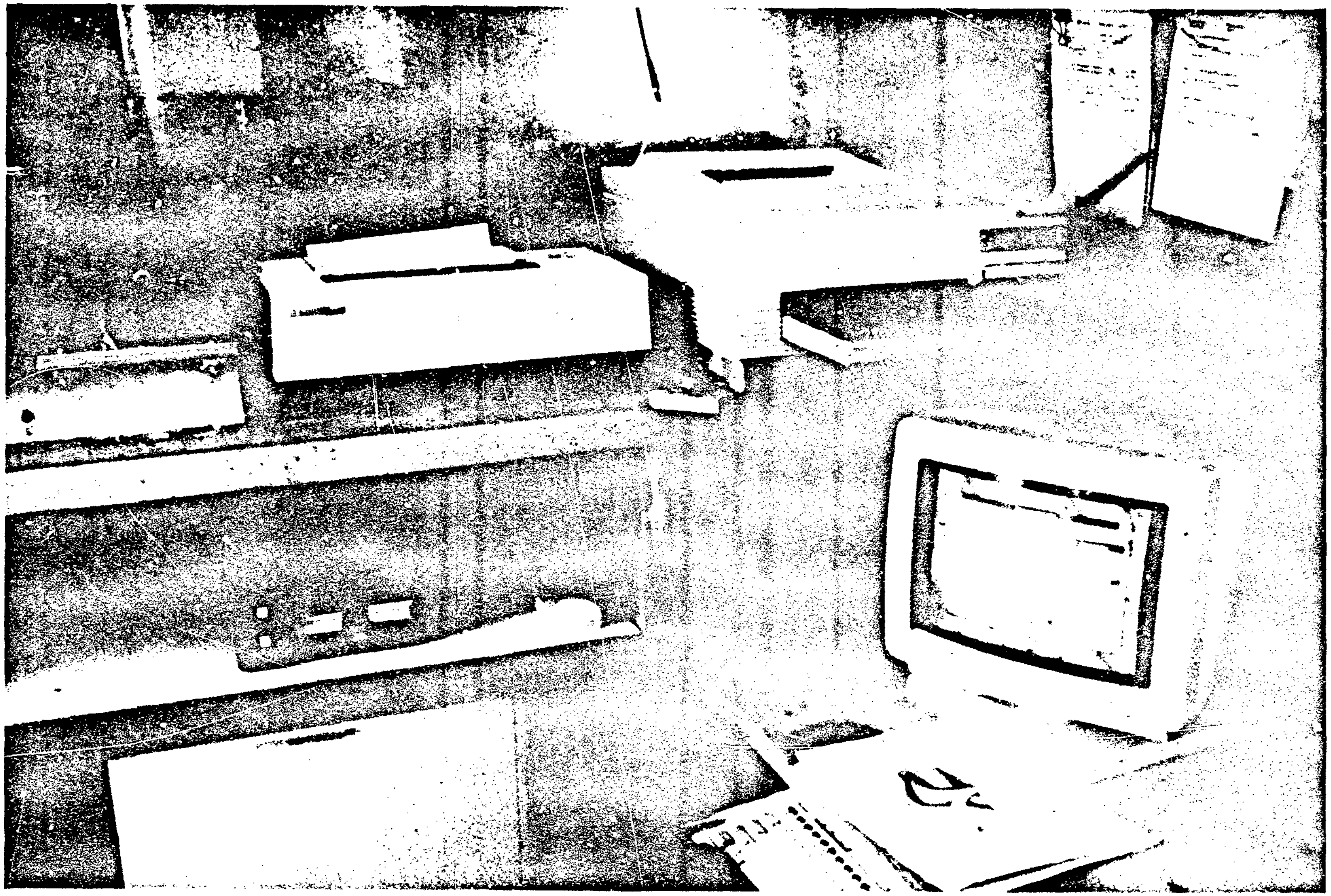


Figure 5. View of data collection and processing section of penetrometer truck.

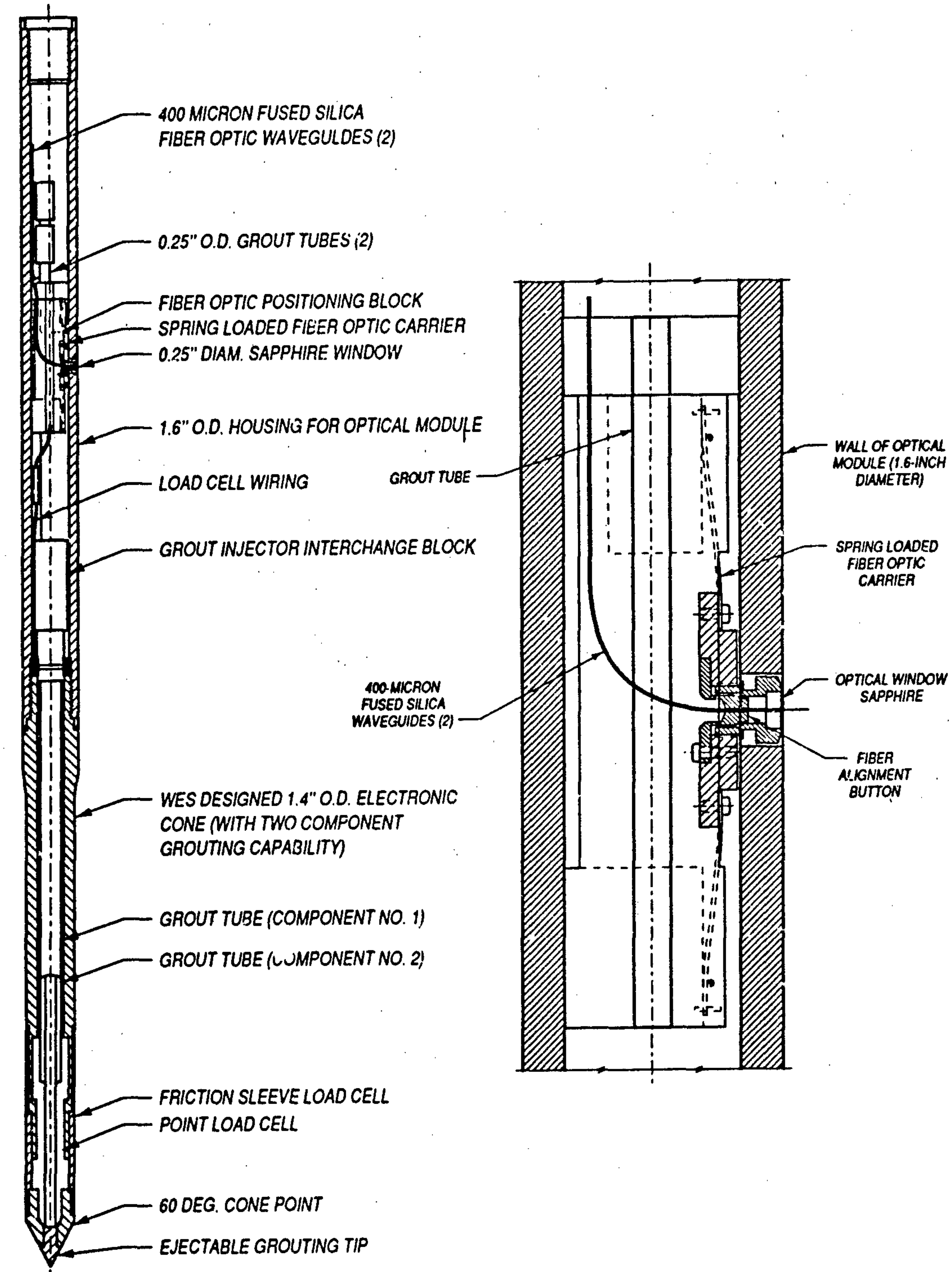


Figure 6. Cross sectional view of penetrometer showing cone, sleeve, and fiber optic components, with close-up of fiber optic window.

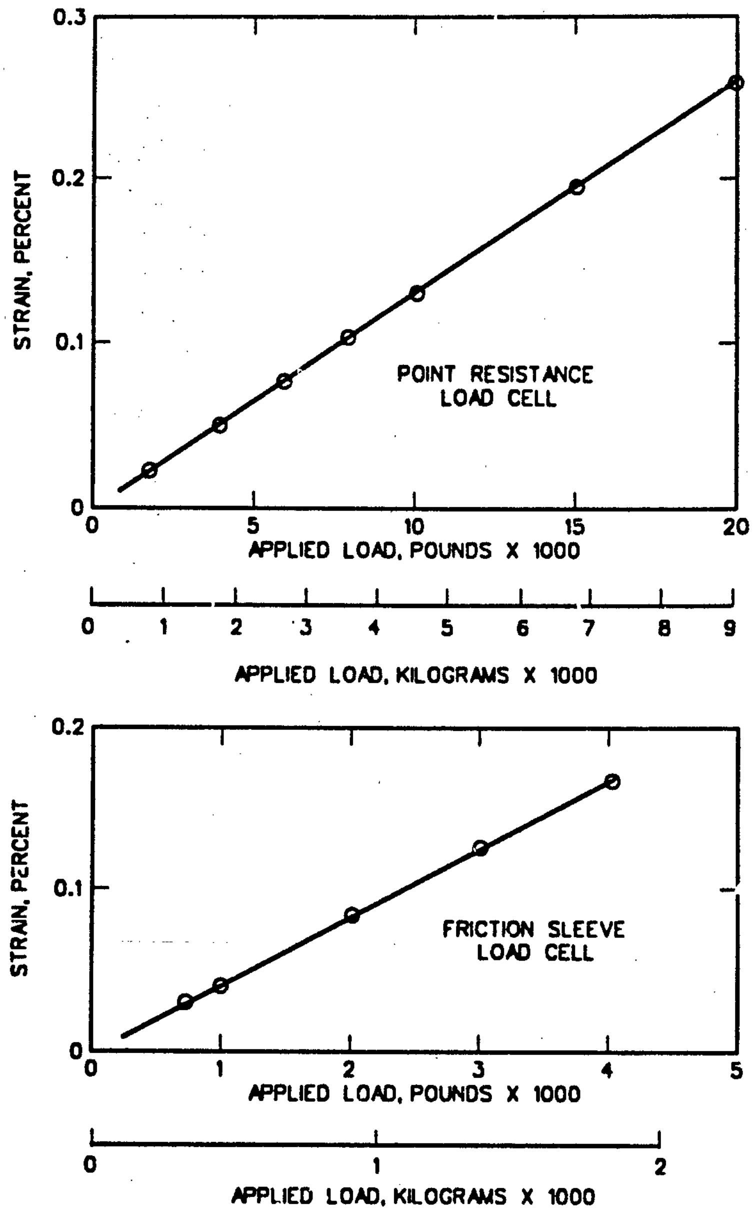


Figure 7 and 8. Calibration curves for point resistance and sleeve friction.

resistance and sleeve friction) made with the cone penetrometer to determine soil type has been well-documented (Olsen and Farr, 1986; Olsen, 1988). The classification scheme used by the SCAPS system was devised by Olsen to identify the types of soils encountered by the CPT probe. An exterior view of the penetrometer portion having the CPT cone and sleeve resistance measurements is shown in Figure 9. The cone resistance measurement, q_c, is recorded with a full Whetstone bridge strain gauge in terms of voltage and converted to bearing pressure typically expressed as tons/ft^2 (tsf). The cone resistance is a measure of the grain-to-grain skeleton strength for sands and silts. As the probe penetrates the soil a "bearing stress bulb" forms in front of the cone tip as shown in Figure 10, which represents soil undergoing plastic flow (e.g. strained to or beyond the peak strength). The size and shape of the pressure bulb is complex but is approximated by cavity expansion mechanisms.

15. The sleeve friction resistance, f_s, is the resistance of the soil as it slides past the friction sleeve. The soil along the friction sleeve is highly strained as a result of passage around the cone tip and during progressive sliding along the length of the sleeve.

16. Soil classification is one of the primary geotechnical engineering properties and is by far the most important parameter for stratigraphy evaluation. The CPT measurements can provide soil classification indexes which are based on soil strength rather than grain size distribution. Geotechnical engineers use soil classification to group similar in situ soil zones into layer groups and then assign engineering strengths, therefore its logical to use a strength based soil classification such as the CPT evaluation. SCAPS utilizes a CPT soil classification chart which uses cavity expansion based CPT normalization as shown in Figure 11. The CPT soil classification technique used for this project is based on normalized (e.g. corrected) CPT measurements to reflect equivalent values at a vertical effective stress of 1 tsf. An overburden vertical stress of 1 tsf represents an equivalent depth below the ground surface of 20 to 30 ft dependant on the water table depth and soil density. For depths of approximately 20 to 30 ft there is little difference between the measured CPT values and the normalized

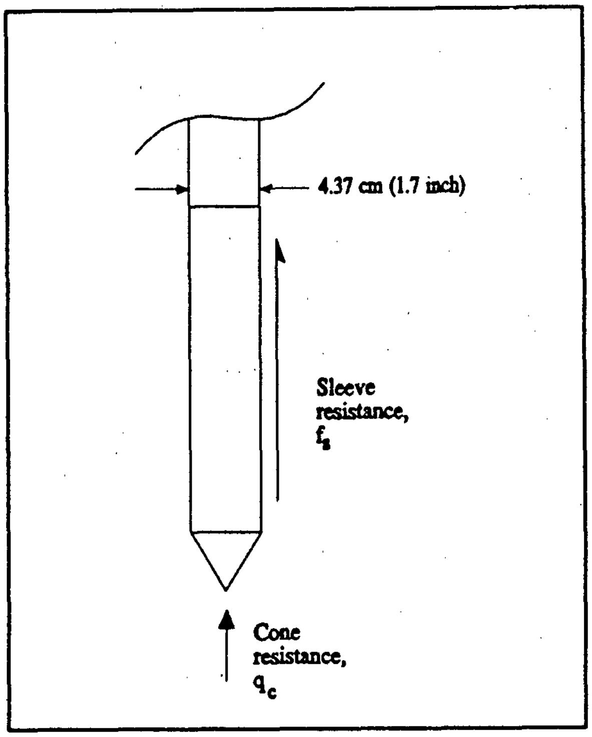
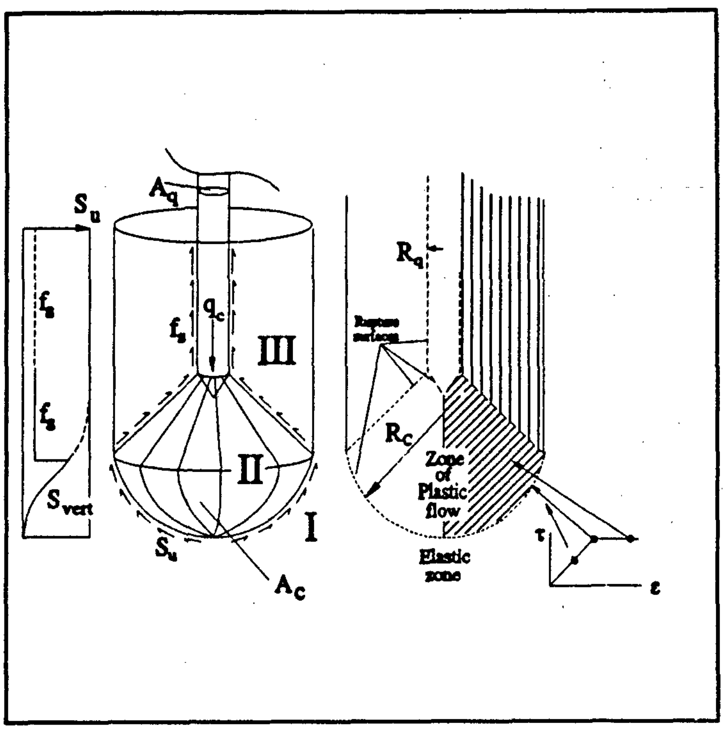


Figure 9. Diagram of cone end showing measurement points for tip and sleeve resistance.

Figure 10. Diagram of bearing stress bulb formed in front of cone tip.



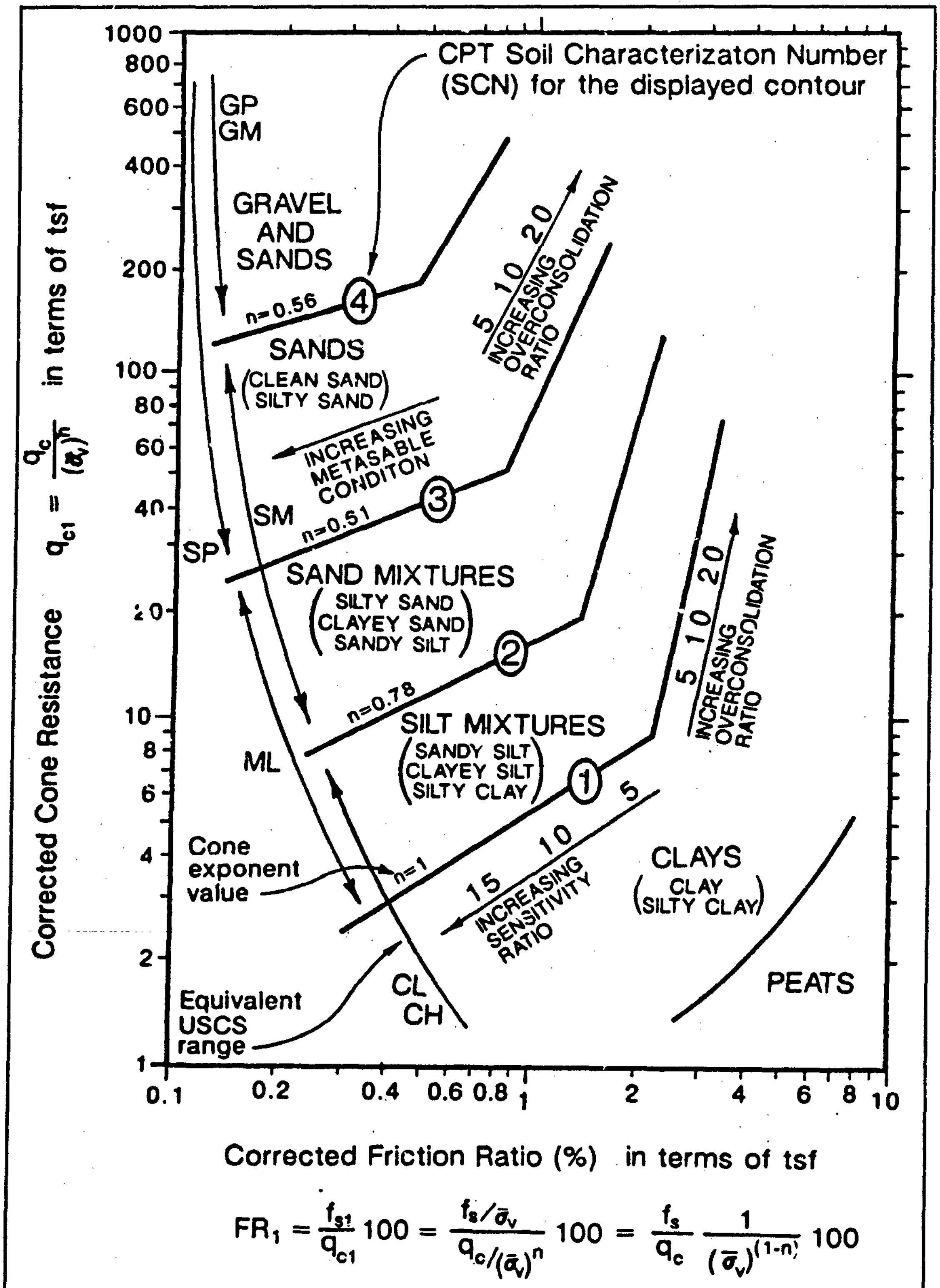


Figure 11. Plot of corrected sleeve friction versus corrected cone resistance for CPT based soil classification.

values. However, at very shallow or deep depths, the technique for cone resistance normalization is very important. At present, direct field use of cavity expansion for cone resistance is not possible because the technique requires knowledge of a number of complex geotechnical properties. The problem is using the correct exponential value which is dependant on soil type. The best technique for normalizing the cone resistance is an empirical technique which is based on cavity expansion and failure envelope curvature trends. Cone resistance normalization can be determined using a variable exponential n value and the vertical effective stress as shown in equation (1). The friction sleeve is normalized as shown in equation (2) without the exponential value because the sleeve measurement is an index of strength. The friction ratio (FR or R_f) is the ratio of sleeve to cone resistance in terms of a percent and has historically been used with CPT soil classification charts. The normalized friction ratio is based on normalized CPT measurements as shown in equation (3).

$$q_{c1c} = \frac{q_c}{(\sigma_v')^n} \tag{1}$$

$$f_{s1} = \frac{f_s}{\sigma_v'} \tag{2}$$

$$FR_1 = \frac{f_{s1}}{q_{c1c}} * 100 \tag{3}$$

where

q_c = measured cone resistance, tsf

q_{c1c} = normalized (corrected) cone resistance to $\sigma_v'=1$ tsf using cavity expansion concepts

f_s = measure friction sleeve resistance, tsf

f_{s1} = normalized sleeve friction resistance

σ_v' = vertical effective stress, tsf

n = exponential for cone normalization

17. The exponential n value for cone resistance normalization reflects

the size of the bearing stress bulb in front of the cone tip (Figure 10). An exponential n value of 1 reflects a linear strength relationship with depth (σ_v') and represents a small stress bulb size. An exponential n value of 0.56 reflects a clean sand having failure envelope curvature together with cavity expansion effects and also represents a very large stress bulb. To determine the correct normalized cone resistance value, q_{c1c}, requires an iterative procedure starting with the lowest exponential n of 0.56. The technique is to initially calculate q_{c1c} (using the assumed exponential n value), f_{s1} and FR_1, then determine the intersection of q_{c1c} and FR_1 on the CPT soil classification chart (Figure 11). The intersection will correspond to a Soil Classification Number (SCN) line with an associated exponential n value. This chart exponential n value will generally not correspond to the assumed exponential value used to calculate q_{c1c}. For calculation stability, the next iteration has an assumed exponential value between the previously assumed n value and chart determined n value. Generally 3 to 6 iterations are required to determine a CPT Soil Classification Number (SCN) that has changed less than 5% from the previous iteration. The Soil Classification Number (SCN) lines shown in the CPT soil characterization chart (Figure 11) represent transition rather than classification boundaries. The SCN transitions do have important meaning only for what they were designed to represent. A SCN of 1 is between a clay and silt mixture classification and represents when there is silt to silt contact within a clay matrix. Therefore a SCN of 1 represents when the silt portion of a clay silt mixture is starting to influence the strength behavior. A SCN of 2 has a classification between silt and sand mixtures and therefore has a strength behavior of a pure silt. A SCN of 3 is between a sand mixture and sand and was designed to represent when the silt mixture of a sand is influencing the total strength. Also, a SCN of 3 should have a fines content (percent passing #200 sieve) of approximately 5 to 10 percent. Figure 12 is a graphical representation between the CPT calculated SCN and Unified Soil Classification System (USCS) codes and general word descriptions of soil classification. Word classifications in Figure 12 have smaller ranges compared to USCS ranges because word descriptors are generally more specific compared to USCS.

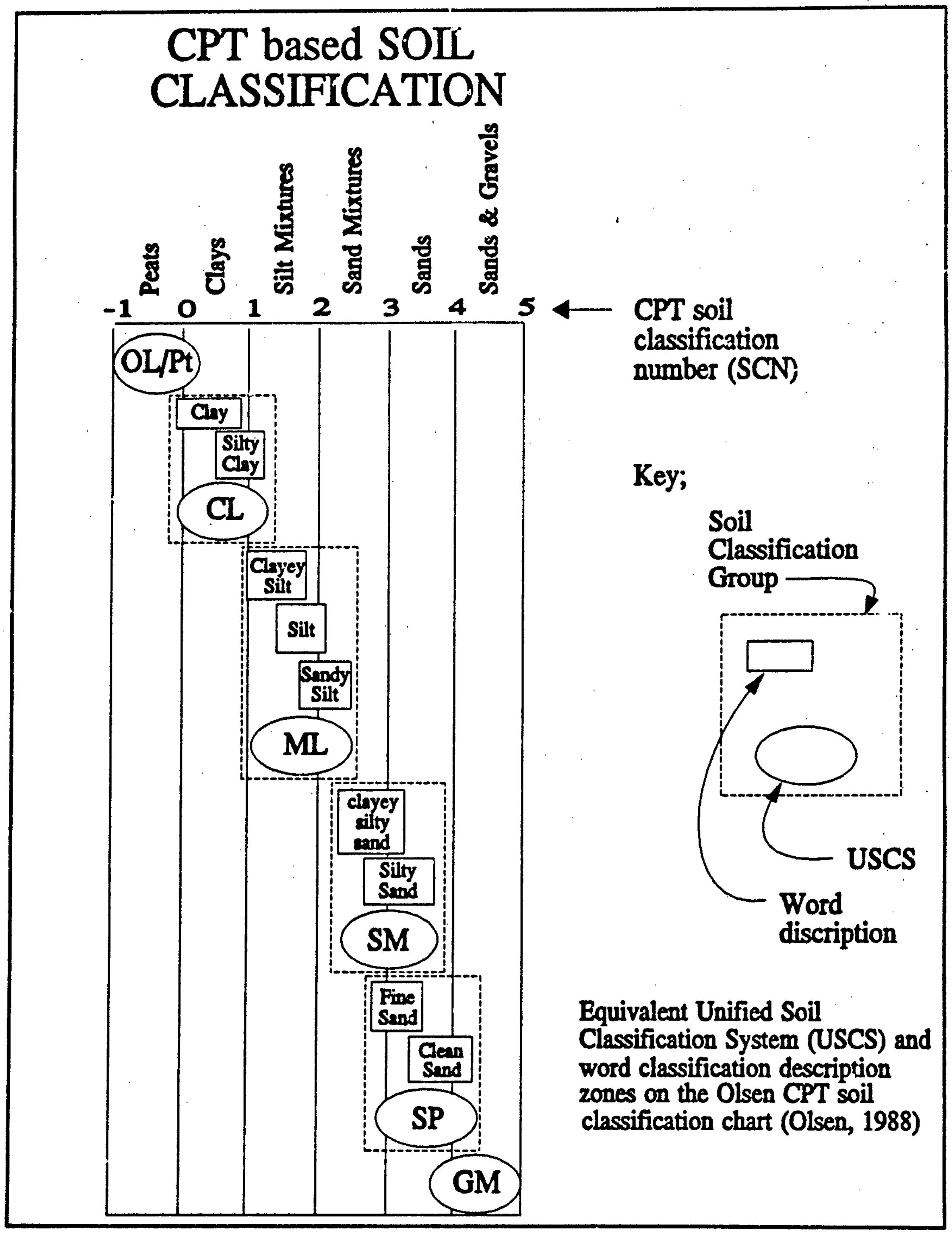


Figure 12. Graphical representation comparing CPT and the Unified Soil Classification Systems.

Soil Fluorescence Measurement Methods

18. The in situ fluorometer (a U.S. Patent has been granted, 1992) was conceived and developed in-house. Lieberman, Inman and Theriault (1989) used a similar fluorometer for measuring POL and metal fluorescence in seawater, and the underlying scientific principle was known to work. A schematic of the system is presented in Figure 13. In making a measurement, the exciting radiation is produced by firing a pulsed nitrogen laser (emitting at 337 nm). The laser light is coupled into two fibers, a timing circuit fiber and the downhole sample irradiation fiber. The light in the timing circuit fiber is used to set the timing for the detector. The major part of the laser pulse is directed into a 250-micron optical fiber that passes down the center of the penetrometer rod. The fiber ends at a 6.35-mm sapphire window that passes the light onto the soil surface adjacent to the window. The fluorescence signal that is a response to the ultra-violet excitation is collected by a second 250-micron fiber and is carried back up through the penetrometer rod to a polychromator. In the polychromator the fluorescent signal is dispersed and the energy distribution at the wavelengths of interest is measured using a linear photodiode array. This system is much faster than the scanning spectrofluorometers. Readout of an entire emission spectrum requires only 15 msec. The rapidity of the readout makes it practical to "stack" or add successive pulses and increase the sensitivity of the unit. Time resolve fluorometry is also possible although this may require holding the window in one position for several minutes.

19. The response of the fluorometer is directly related to the concentration of aromatic compounds in the soil. Fluorescence of any aromatic compounds with basic or acid functional groups is usually pH dependent. Ionized aromatic compounds will fluoresce at different wavelengths and at different intensities from the same compounds in a nonionized state. Fluorescing compounds adsorbed on solid surfaces will typically fluoresce with greater intensity than the same compounds in solution. Decomposition or weathering phenomena also change the fluorescence of fuels. Generally the aromatic (ring) compounds that fluoresce are concentrated in the weathering process because the lighter hydrocarbons volatilize and the longer straight-

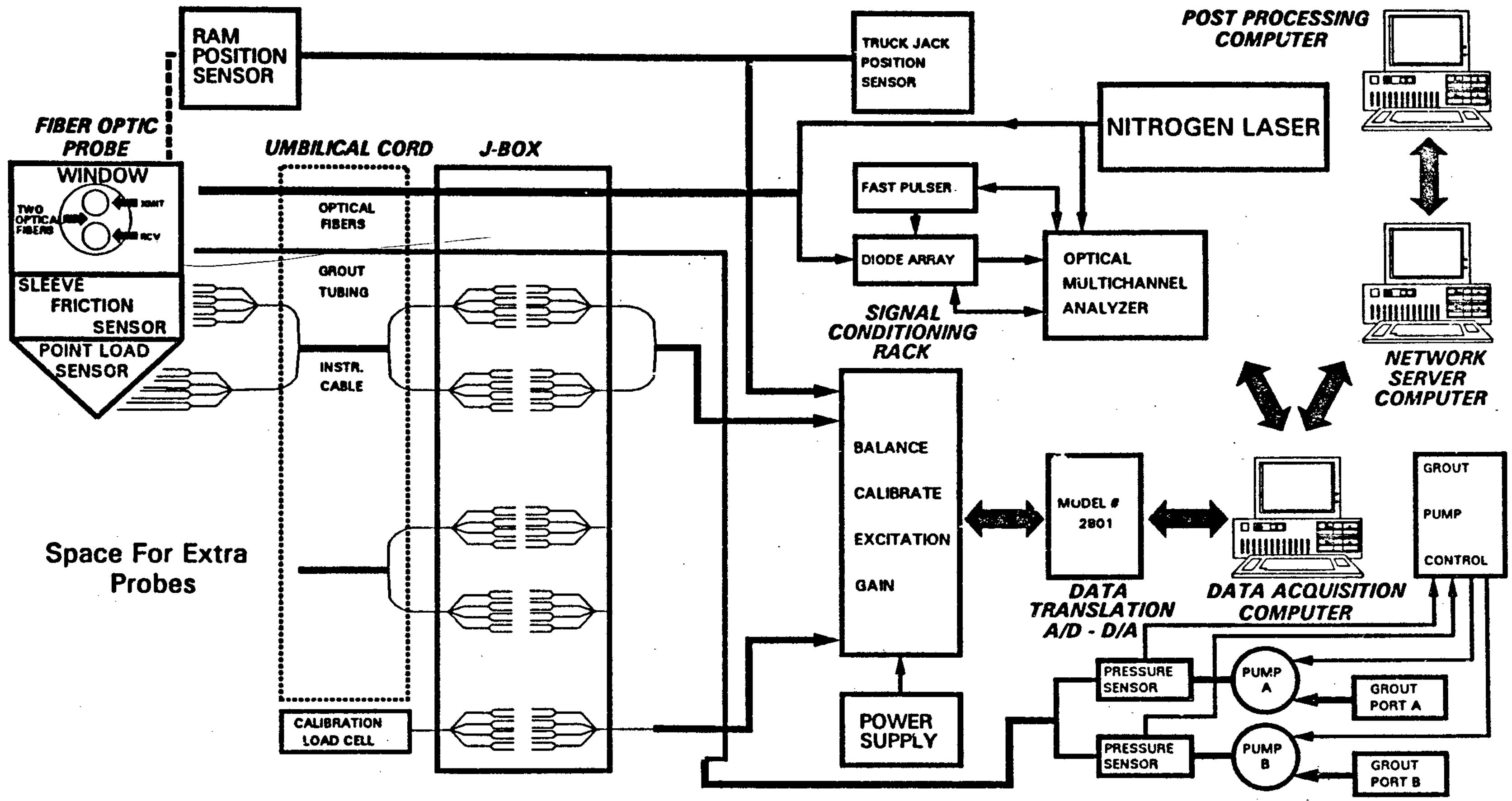


Figure 13. Flowchart of fiber optic system.

chain hydrocarbons are more easily decomposed by microbial activity.

20. Each fluorescence spectrum consists of photon counts measured at 1024 points (over a wavelength range of 300 to 800 nm) for every 2-cm (0.8-in.) layer of soil investigated. The present data processing system records all spectral intensity measurements and makes corrections for instrument drift during measurement. The corrected data are screened to develop the photon counts for the peak of interest and the background. A file containing the single equivalent normalized counts, the map coordinates, and the depth below a surveyed datum is prepared from the spectral data. The final data file is transformed into a 3-dimensional gridded file and is plotted using a visualization program.

Data Acquisition

21. The data acquisition system and the post processing system each have a separate control computer. The two computers are linked by a network so that data can be exchanged during and after the penetration testing. The data acquisition computer controls all systems and stores the data on a demountable hard disk during the penetration test. The major block of data is generated by the soil fluorometer system in the optical multichannel analyzer (OMA). The OMA is a separate computer that is controlled by the data acquisition computer through a general purpose interface bus. The data acquisition is also interfaced directly with; the amplifier/filter components for the measurement of strain on the cone tip and sleeve, amplifiers for the electrical resistivity measurements, a variable potentiometer that reads out the position of the hydraulic rams (data used to calculate the depth of the penetrometer tip), and the computer network.

Computerized Site Characterization/Visualization

22. Penetrometer data were interpreted with the help of 3-dimensional visualization software (Interactive Volume Modeling, IVM) developed by Dynamic Graphics, Inc. on a Silicon Graphics work-station. The IVM program accepts scattered data files in ASCII format and creates a uniform 3-dimensional grid.

Smooth extrapolation and interpretation for points is used to create grid values within and near the existing data. A lateral clipping plane is created to clip extrapolated data outside the bounds of the original data. The basic data controls the location of each known value but the aspect of the final 3-dimensional shapes produced from a data set can be altered by varying the weighting on the 3-dimensional grid derived from the original data. Typically the weighting values for the derived grid are selected by examining 3-dimensional volume plots and observing which spacing combination produces a plot that most closely agrees with the original data points. The software is referred to as "modeling" by the vendor. In the opinion of the authors, these are interpolation with extrapolation processes and not modeling as the term is commonly used in engineering or physical sciences.

23. A completed 3-dimensional visualization model is presented as a series of surfaces that represent specific values of the variable under study. The plot of the surfaces can be presented as a series of drawings of the site or as a computer-generated video that shows the soil volume with the data boundaries presented in varying colors. The IVM software can rotate the volume so that the limits of the parameter can be observed from all sides. Subprograms are available that allow the volume model to be sliced at various points so that the variation of the parameter can be observed inside the projected volume.

PART III: SITE DESCRIPTIONS

Regional Geology

24. PNSY is located on League Island, approximately 4 miles south of downtown Philadelphia. Originally a marshy area, extensive filling operations eliminated much of the marshlands and formed what is presently PNSY. The base is underlain by unconsolidated Coastal Plain sediments, which are underlain in turn by a metamorphic bedrock at depths of 100 to 250 feet. The sandy units within the sedimentary strata are aquifers with intervening clayey units serving as confining layers.

25. The surficial deposits in the Philadelphia area consist of Pleistocene sand, gravel, and glacial outwash deposits. The maximum thickness of these deposits is about 80 feet and the typical thickness is about 40 feet. The dominant material is brown to gray sand and gravel composed of medium to fine grained, angular to rounded quartz sand grains, and pebbles and boulders of sandstone, siltstone, chert, quartzite, and mica schist. Along the Delaware and Schuylkill rivers, most of the Pleistocene deposits have been removed by erosion. In the vicinity of PNSY, where the two rivers merge, recent deposits of dark gray mud, silt, and fine sand reach a maximum thickness of 78 feet.

26. The hydraulic gradients of both the unconfined surficial aquifer and the underlying confined system originally sloped toward the valley of the Delaware River, and the aquifers discharged to the Delaware River and its tributaries. In the vicinity of PNSY, the water table aquifer discharged directly to the Schuylkill and Delaware rivers. Heavy industrial and municipal withdrawals in New Jersey, however, may have reversed the natural hydraulic gradients. The regional hydraulic gradients apparently now slope southeast, towards the New Jersey pumping centers. At PNSY, therefore, water flows into the surficial aquifer from the Schuylkill and Delaware rivers. Groundwater within the surficial aquifer flows downward through the confining layers and into the heavily pumped deeper sand units.

Wharf E

27. The location of the site designated Wharf E is shown in Figure 14, and in detail in Figure 15. All cone penetrometer probes in this location, with identifying numbers, are also shown in Figure 15. A large portion of the site had undergone excavation activity to remove known contaminated soil, from petroleum storage tanks which were formerly on the site. Five feet of material had been removed from approximate elevation 13 ft to approximate elevation 8 ft. The resulting irregular shaped pit was the central focus of probes in the area, with a few probes located outside the pit for verification purposes. Material exposed in the pit was of a sandy, silty, gravelly nature, with some gravels being quite large. During a large portion of the testing, water was standing in the pit to a depth of one foot.

28. A combination of the excavation, and damp site conditions did not permit access into the pit with the cone penetrometer truck. All pushes in the pit were accomplished by means of the specially designed portable platform positioned with a crane.

Wharf G

29. The location of Wharf G is shown in Figure 14, and in detail in Figure 16 with all probe locations identified. This site is known as the "fuel farm" and consist of varying sizes of surface and underground tanks. The facility serves as the main petroleum storage and distribution site for the base. There are three underground tanks at the site which were the focus of all probe pushes in the area. The tanks are actually only partially underground with soil mounded around each one.

30. In the vicinity of the probes, a monitoring well existed which had shown petroleum contamination from previous samples taken. From the samples taken at the monitoring well, the product appeared to be floating on the water table.

31. The site presented several problems hindering the use of the cone penetrometer truck for making the pushes. The surface tanks had a small

1

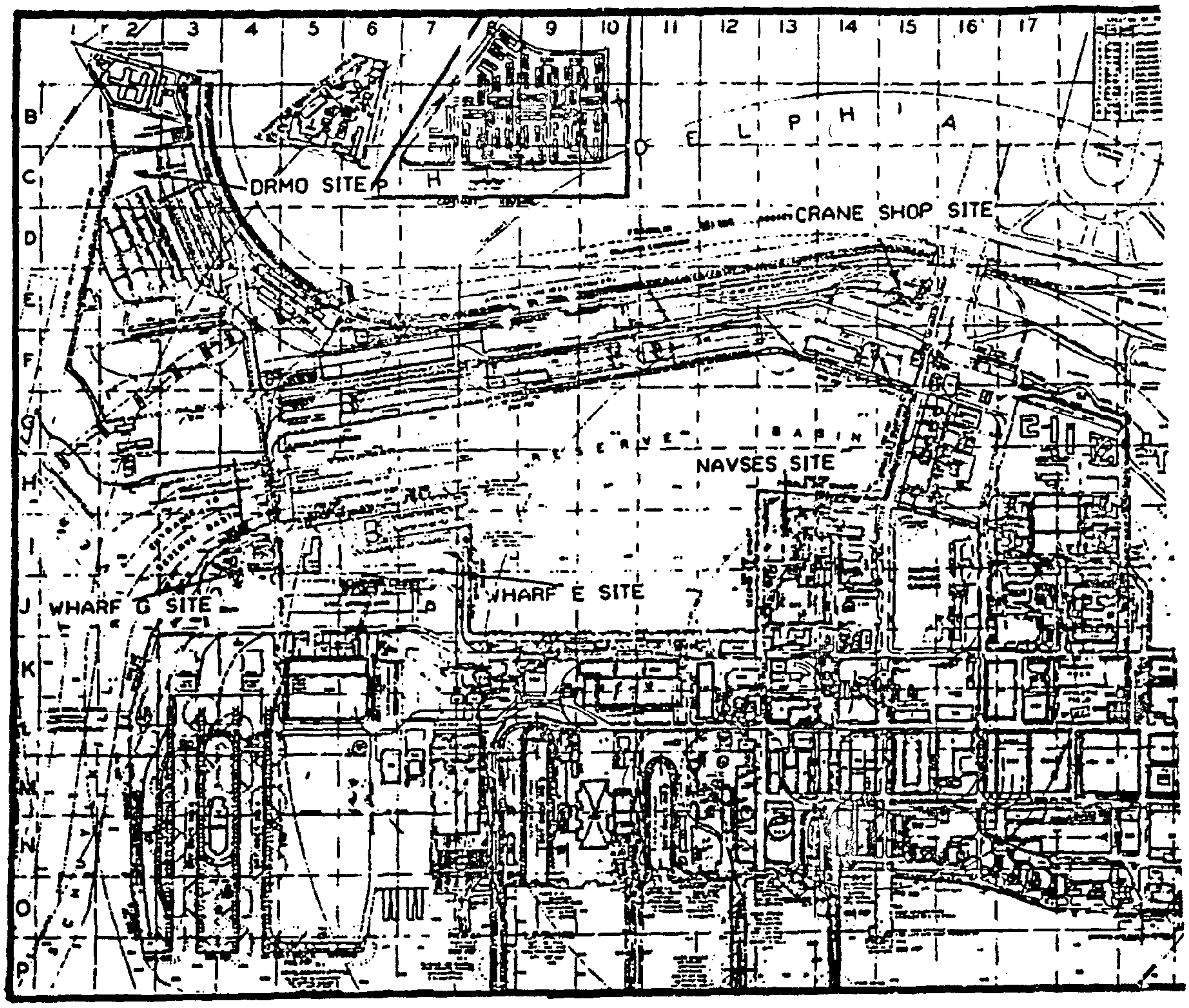
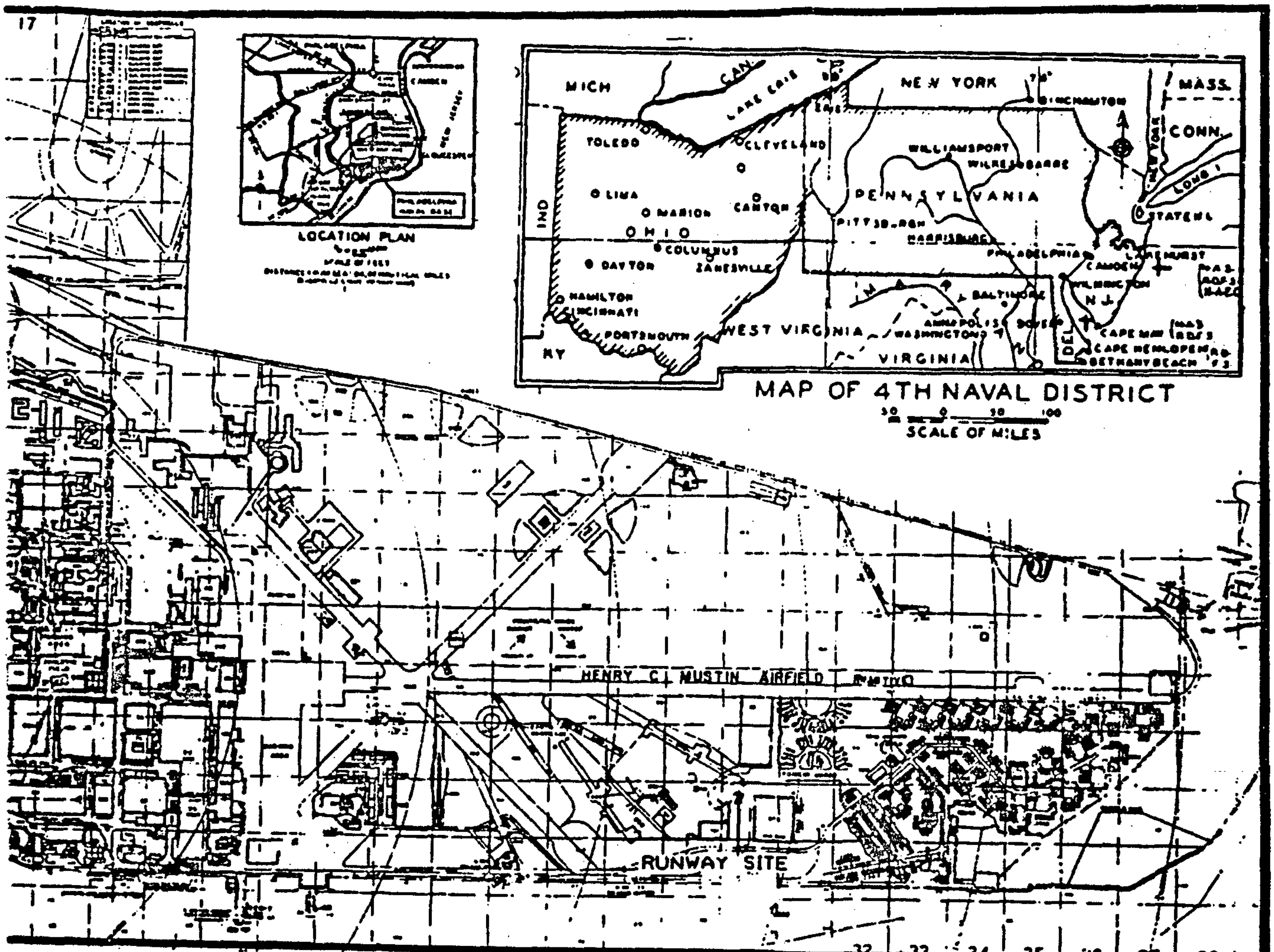


Figure 14. Site map showing the location of ea
at PNSY (DRMO, Wharf G, Wharf E,

2



:ation of each of the seven areas investigated
, Wharf E, NAVSSES, Crane Shop, and Runway).

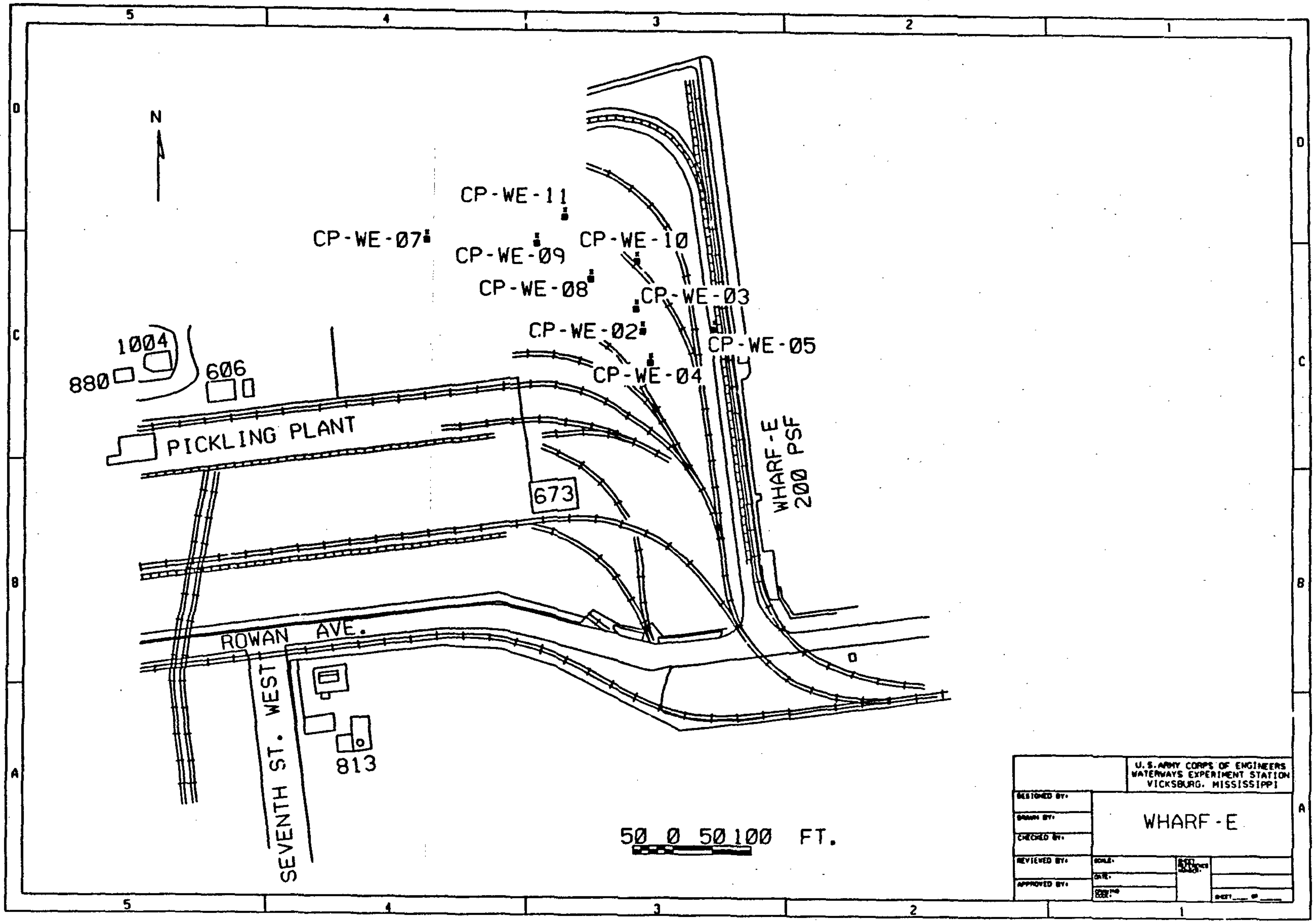


Figure 15. Detail of the Wharf E site showing all probe locations.

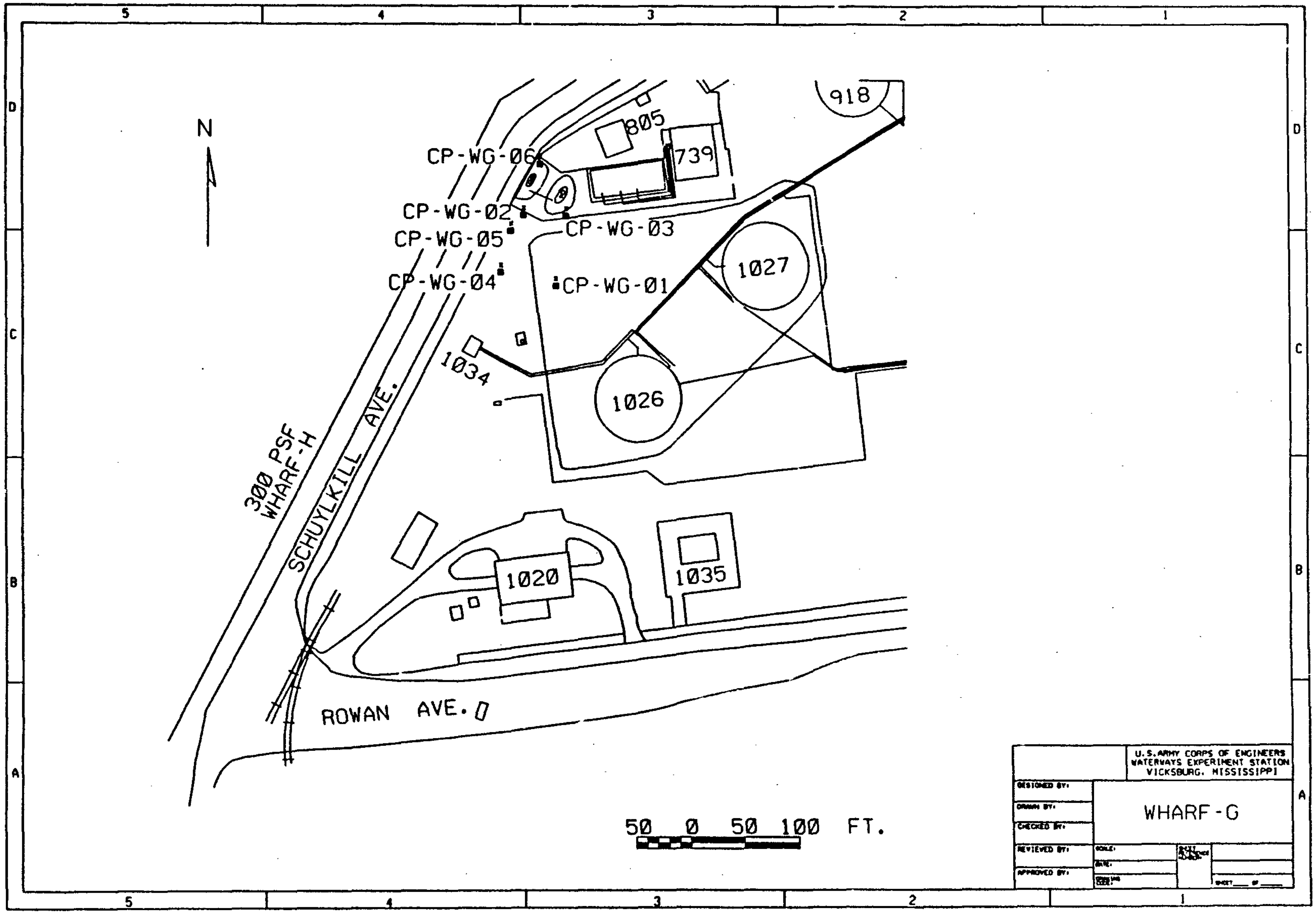


Figure 16. Detail of the Wharf G site showing all probe locations.

retainer berm around them which prevented access by the truck. Also, the underground tanks were fenced off and afforded very little room to maneuver around them. These two factors dictated the use of the portable platform for all pushes in this area.

DRMO Facility

32. The location of the Defense Reutilization and Marketing Organization (DRMO) facility is shown in Figure 14, and in detail in Figure 17 with four probe locations identified. This facility serves as a recycling center, and as such maintains a wide variety of materials. The facility also maintains an oil-water separator, which was the focus of probes in this area. There were visible petroleum products on the ground surface around the separator. Adjacent to the separator is a large concrete slab, with a concrete retaining berm, where 55 gal drums are stored.

Crane Shop

33. The location of the large crane workshop is shown in Figure 14, and in detail in Figure 18 with all probe locations identified. This facility serves as the repair shop for all large cranes on the base. Two areas were investigated at the crane shop, the first being adjacent to the shop building, and the second parallel to the fence that marks the base boundary. The area adjacent to the shop building had recently had a leaking underground storage tank removed. The hole was backfilled with a gravelly sand. Probes in this area were to determine if any petroleum products leaked from the removed tank remained in the soil. The second site centered around an area that had been used as a storage location for petroleum products needed to support the shop activity. All material had been removed from the location, and some surface staining was visible.

NAVSSES Tank Farm

34. The location of the Naval Ship Systems Engineering test facility is shown in Figure 14, and in detail in Figure 19 with the three probe locations at this site identified. This facility serves as a testing site for all

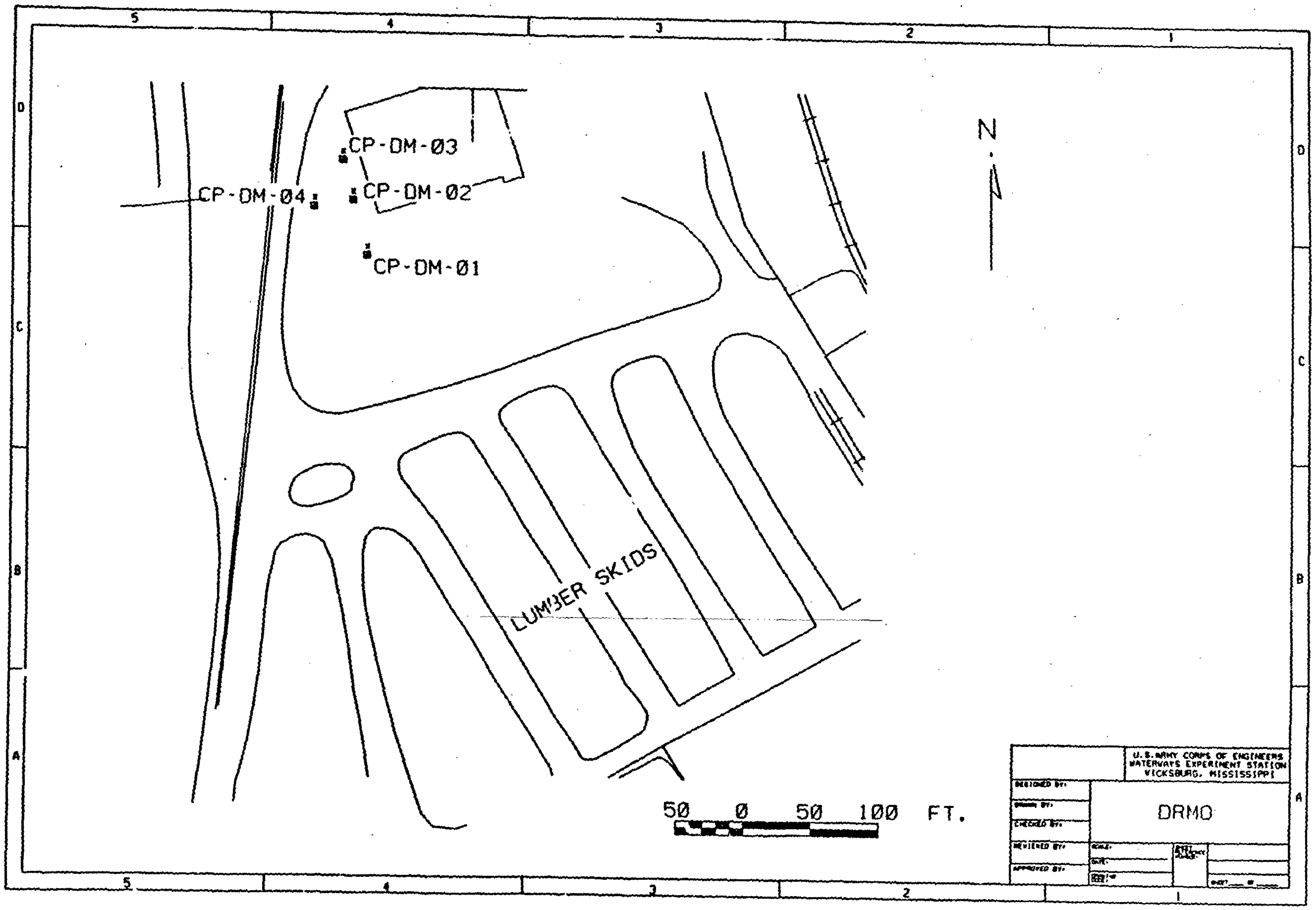


Figure 17. Detail of the Defense Reutilization and Marketing Organization site showing all probe locations.

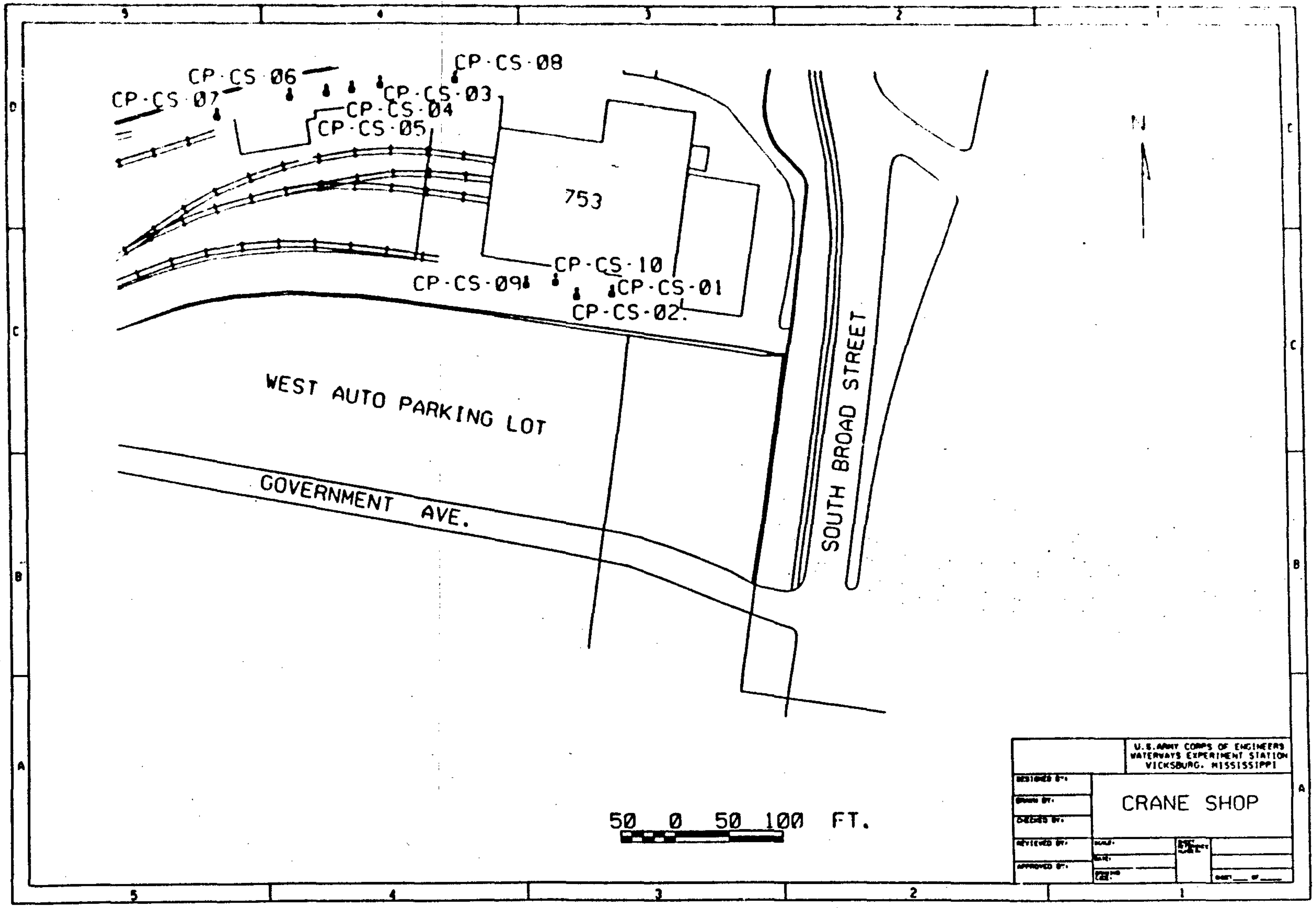


Figure 18. **Detail of the Crane Shop site showing all probe locations.**

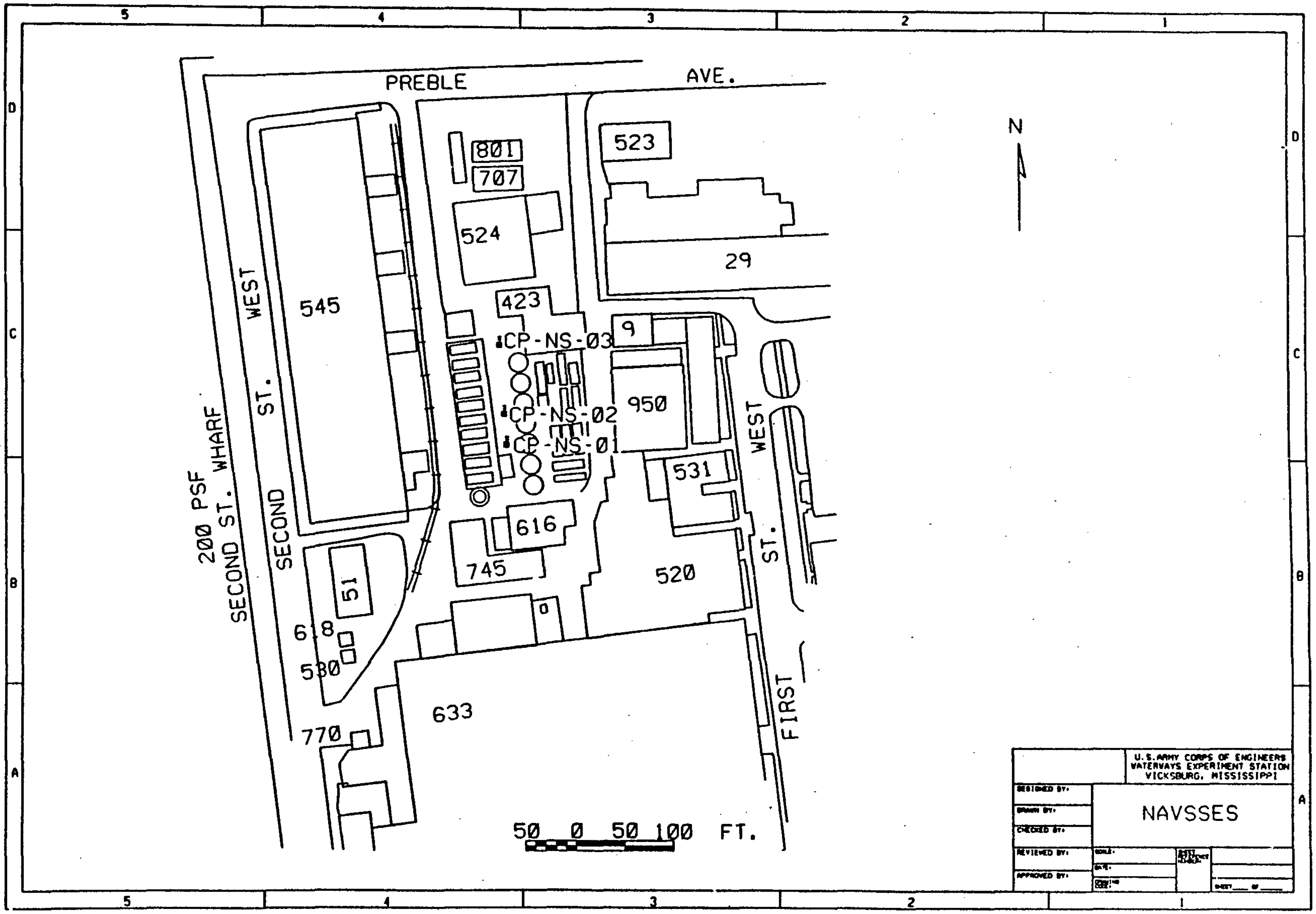


Figure 19. Detail of the NAVSSES site showing all probe locations.

petroleum products used to support the naval vessels at the base. The petroleum products used for testing are stored in a small tank farm located at the facility. Probes at this site were in the tank farm area.

Runway

35. The location of the Runway site is shown in Figure 14, and in detail in Figure 20 with all probe locations identified. This site is at the edge of the old Mustin Field runway, which is now inactive. The site consist of two underground storage tanks that remain in place, and are believed to contain sand blasting grit residue. Probes at this location were centered around the underground tanks.

General

36. Each one of the sites investigated at PNSY presented a unique challenge for the site characterization equipment. The overburden at the base, in general, contained some rather large gravels probably better described as small boulders. The first push attempted at the base encountered one such boulder and resulted in a broken probe. Therefore, almost every push was preceded by a pre-push, with a slightly smaller but more durable probe, to create a pilot hole. The pre-push probe is simply a mechanical device with no instrumentation attached. This technique did not allow for the collection of soil property data but it did permit the collection of fluorescent data. This was agreed to by the sponsor since each site investigated had soil samples taken and analyzed prior to the WES trip. It was agreed that the soil stratigraphy was not an important factor for the purposes of the investigation, as compared to the risk of damaging more probes.

37. Many of the sites required the use of specialized equipment to prepare them for probing. Much of the area is paved, which required the use of a jackhammer and backhoe to make an opening through the pavement (Figure 21). Many of the sites were not accessible to the cone penetrometer truck and forced the use of the portable platform specially adapted for the work at PNSY. Movement of this platform from site to site and placement at each site

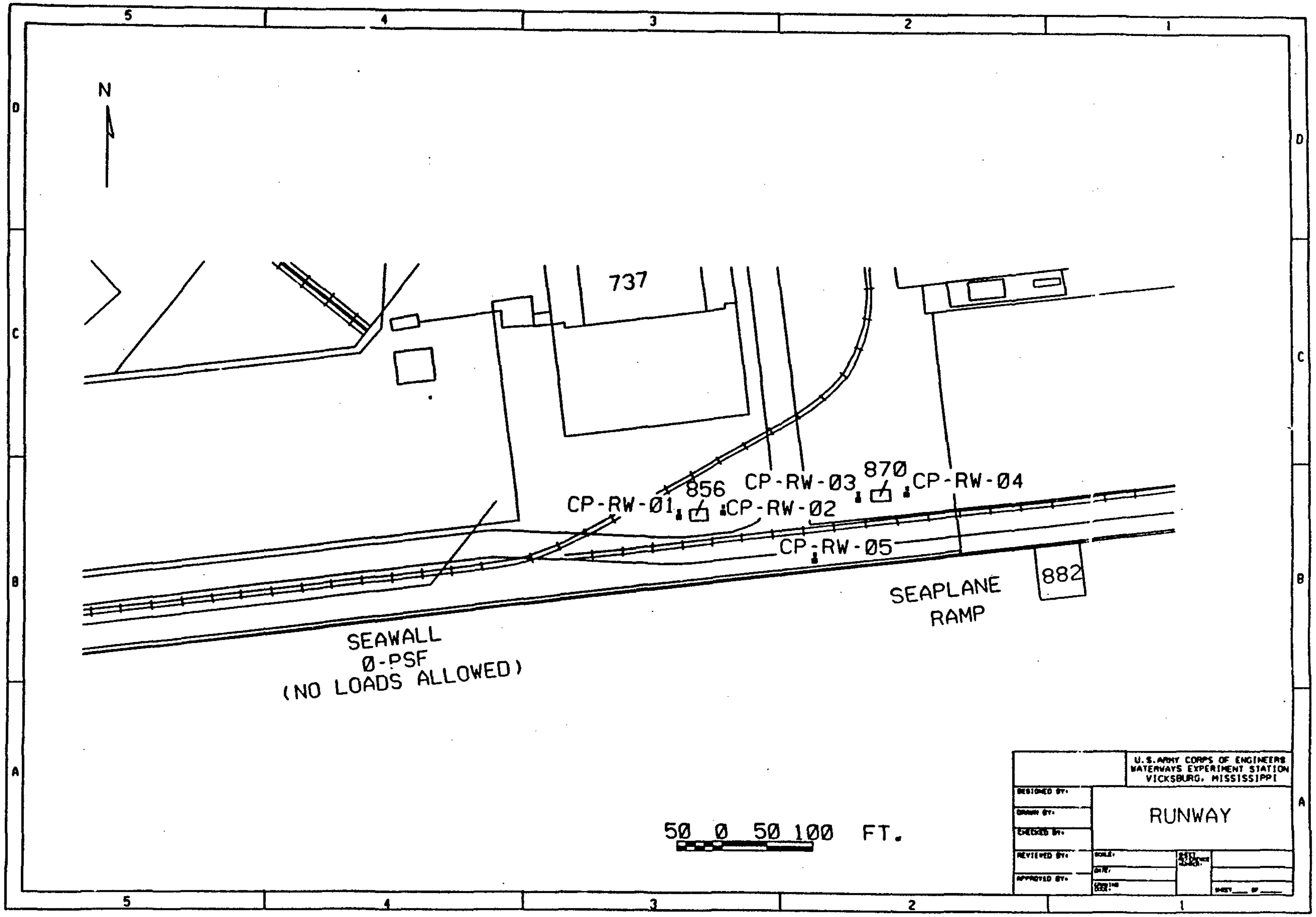


Figure 20. Detail of the Runway site showing all probe locations.

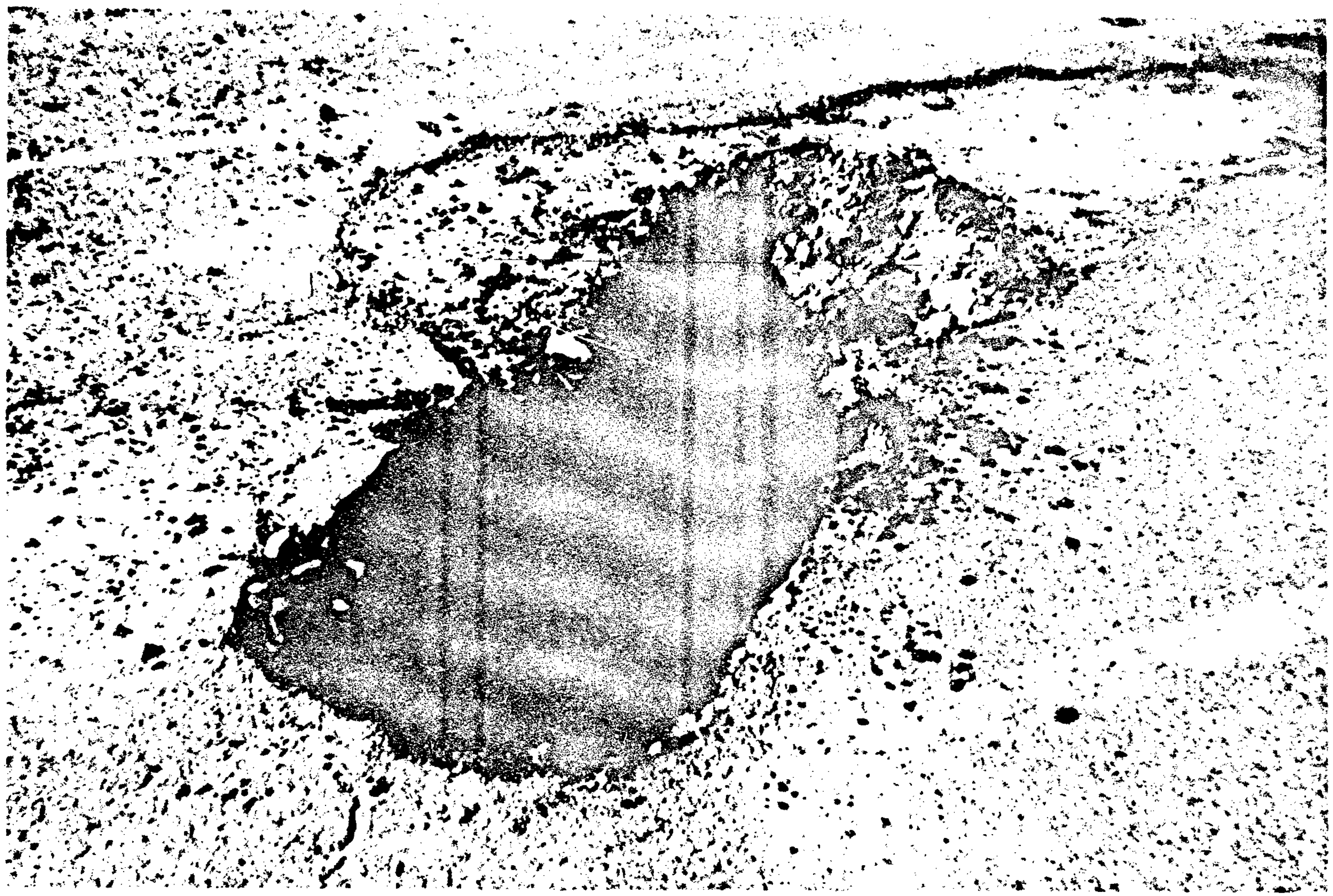


Figure 21. Photograph of cavity through pavement for penetrometer investigation.

required the use of a tractor trailer and a large crane. All of these factors combined to make the work considerably slower than what is normally achievable.

PART IV: RESULTS AND DISCUSSION

General

38. Results from the cone penetrometer work performed at the PNSY are presented in two forms. The results for each probe are presented as a series of panels in two dimensional form and as a three dimensional volume representation. The two dimensional figures each contain seven panels presenting various probe results as a function of depth. The first panel is a plot of the cone resistance (tip), and the second panel a plot of the sleeve friction, both are corrected values in units of tons/ft^2. The first two panels (tip resistance and sleeve friction) are used to determine the third panel of CPT based soil classification. This plot gives a continuous profile of soil classification for the entire depth of investigation and is based on the chart presented in Figure 11. The first three panels represent the geotechnical data collected at the site while the fourth through seventh panels represent the fluorescence data. As previously discussed, due to the use of pilot holes on many pushes geotechnical data was not collected for every probe. In these instances the panels are labelled to reflect that information. Also, many of the probes did not start at the ground surface since a small cavity resulted from the process of puncturing the pavement. In the cases where the probe did not start at the ground surface, a label has been placed on the cone resistance panel (first panel) to indicate where the cavity was located.

39. The fourth through seventh panels represent the fluorescence data collected at each site, respectively. The fourth panel is a plot of fluorescences intensity single equivalent normalized counts. At each depth of data collection (every 2 cm) the fluorescence intensity returned from the soil being sampled is recorded in terms of counts. Low counts referring to very little fluorescence and high counts referring to high fluorescence. The counts are then normalized by adjusting them to the calibration data recorded at the start and end of every push. In addition the counts are referenced to a standard (Rhodamine calibration of 10,000 counts) so that every probe regardless of the site conditions can be compared one to another. The panel

shows the minimum resolution of the SCAPS fluorescence system, which is approximately 100 single equivalent normalized counts. Values below this range are attributable to resolution difficulties and can not be considered representative of conditions in the sub-surface.

40. The fifth and sixth panels convert fluorescence intensity single equivalent normalized counts into predicted parts per million (ppm). Panel five presenting the data on a linear scale and panel six on a logarithmic scale. While at PNSY, samples of soil were collected at various locations to be used for calibration purposes. These samples were collected as "grab" samples at a location and depth determined from the penetrometer fluorescence data. Samples were collected at locations that revealed no contaminants in the soil and at locations where contaminants were identified. These samples were analyzed at WES to determine total oil and grease, total recoverable petroleums and hydrocarbons (TRPH), and aromatics in ppm. The aromatics were determined by use of a gas chromatograph. Procedures for testing material for each of the three constituents listed above can be found in any sampling or laboratory procedures book. The same samples were also analyzed with the fluorescence system to determine the single equivalent normalized counts. A plot of counts versus ppm was made, and a best fit line was applied to produce an equation that could be used to convert counts to ppm (Figure 22). The data presented in the plots is based on the conversion of counts to ppm using the equation obtained from the TRPH data. The total oil and grease data gives numbers that should be high because of the inclusion of the greases which do not fluoresce. The aromatic data should give numbers that are low because it only includes a portion of the total fluorescent potential of a material. The TRPH is believed to be most representative of what is actually being obtained from the SCAPS system. The seventh panel is the wavelength that corresponds to the peak counts, which are connected in the area of maximum fluorescence intensity.

41. On each of the two dimensional figures presenting the results of a single probe (seven panels), a legend is located at the bottom containing information about the probe. The values that appear for North, East, and Elevation are in the State Plane Coordinate System. To determine where the

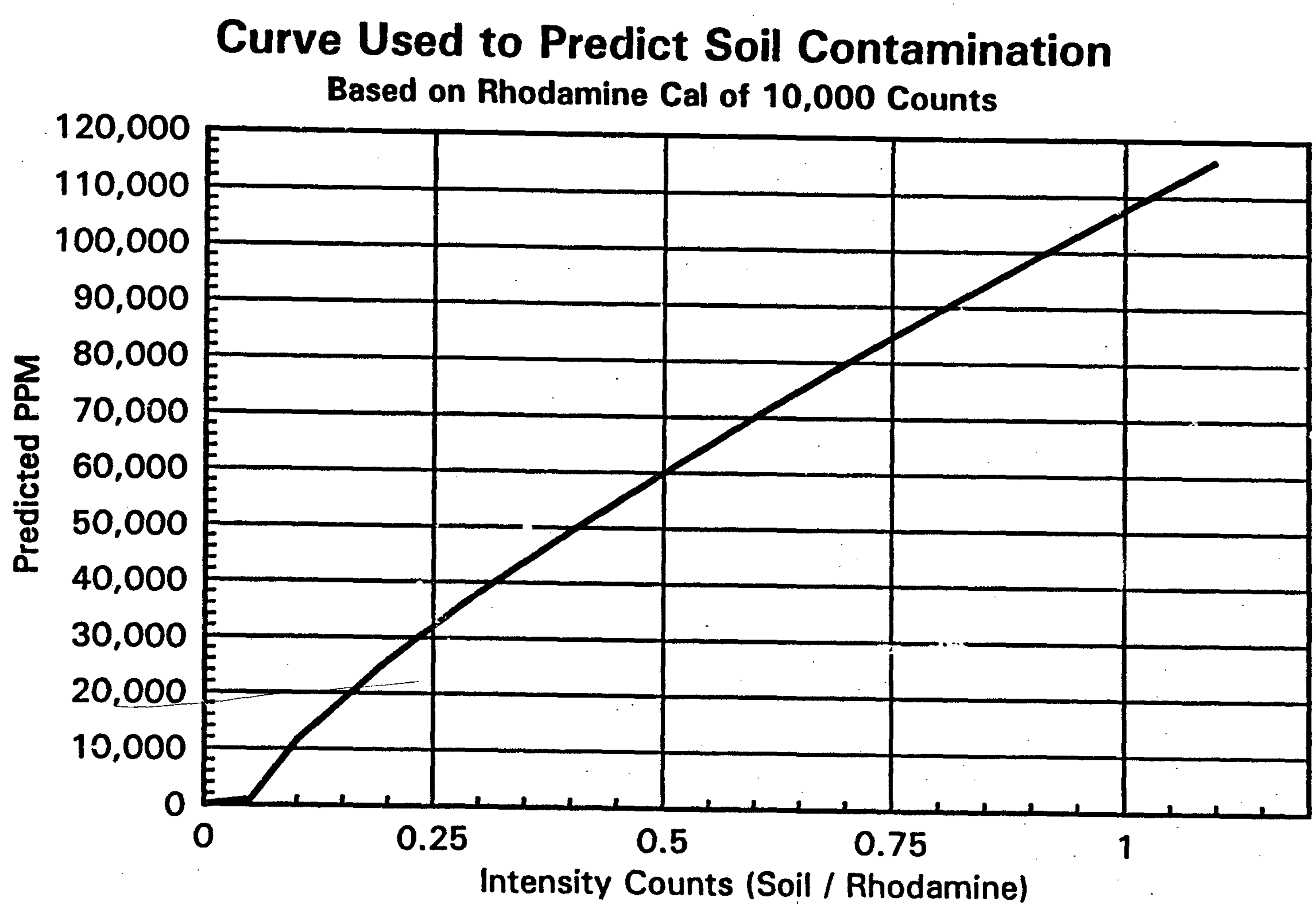


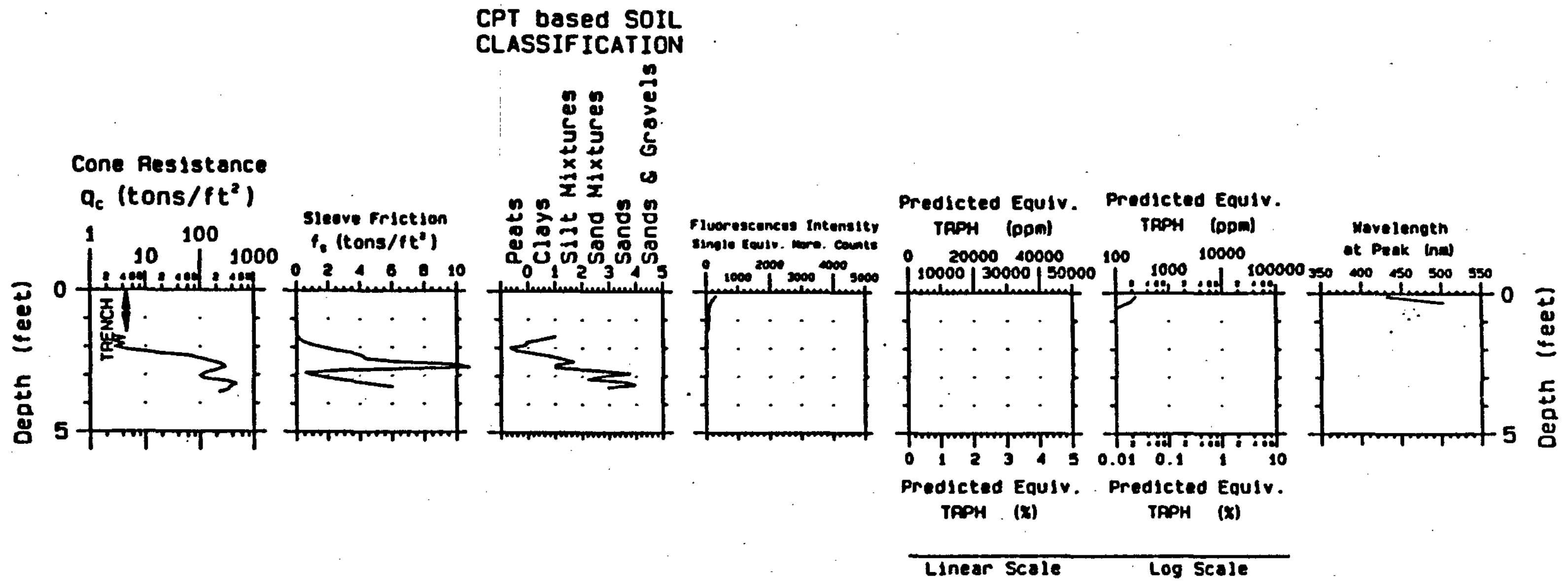
Figure 22. Calibration curve develo[illegible] for PNSY of counts versus ppm.

probes are located, reference is made to the site maps. In the lower left corner of the legend is located the site zone and probe name. The site zone is the name given to each site and corresponds to the sites discussed in Section III. The probe name is a WES naming convention to identify each push, and also corresponds to the names used to identify pushes referred to in Section III. For example, "CPT; CP-WE-02" is the name identifying cone penetrometer push, cone (C) penetrometer (P) data, Wharf E (WE), number two. To locate this push, the site map corresponding to Wharf E would have a point on it labelled CP-WE-02.

42. The data are also presented in the form of three dimensional volumetric models representing sub-surface conditions. The field data are analyzed by sophisticated three dimensional data interpolation algorithms. The gridded data are then formed into a three dimensional volumetric image of the subsurface soil conditions or of the body of contaminated soil. Varying properties of the material (soil stratigraphy or contaminant concentrations) are displayed as different color zones for use in geotechnical engineering applications. The image can easily and rapidly be manipulated in a number of ways to allow viewing the object from all angles. The location of all data points used to create the gridded data are displayed on the figure. Due to the magnitude of data collected (every 2 cm) the posted data appear as a solid line. A two dimensional plan map of the site investigated can be added to the figure to aid in feature locations. In the lower left corner of the figure is a legend presenting the color zones and corresponding values represented.

Wharf E Results

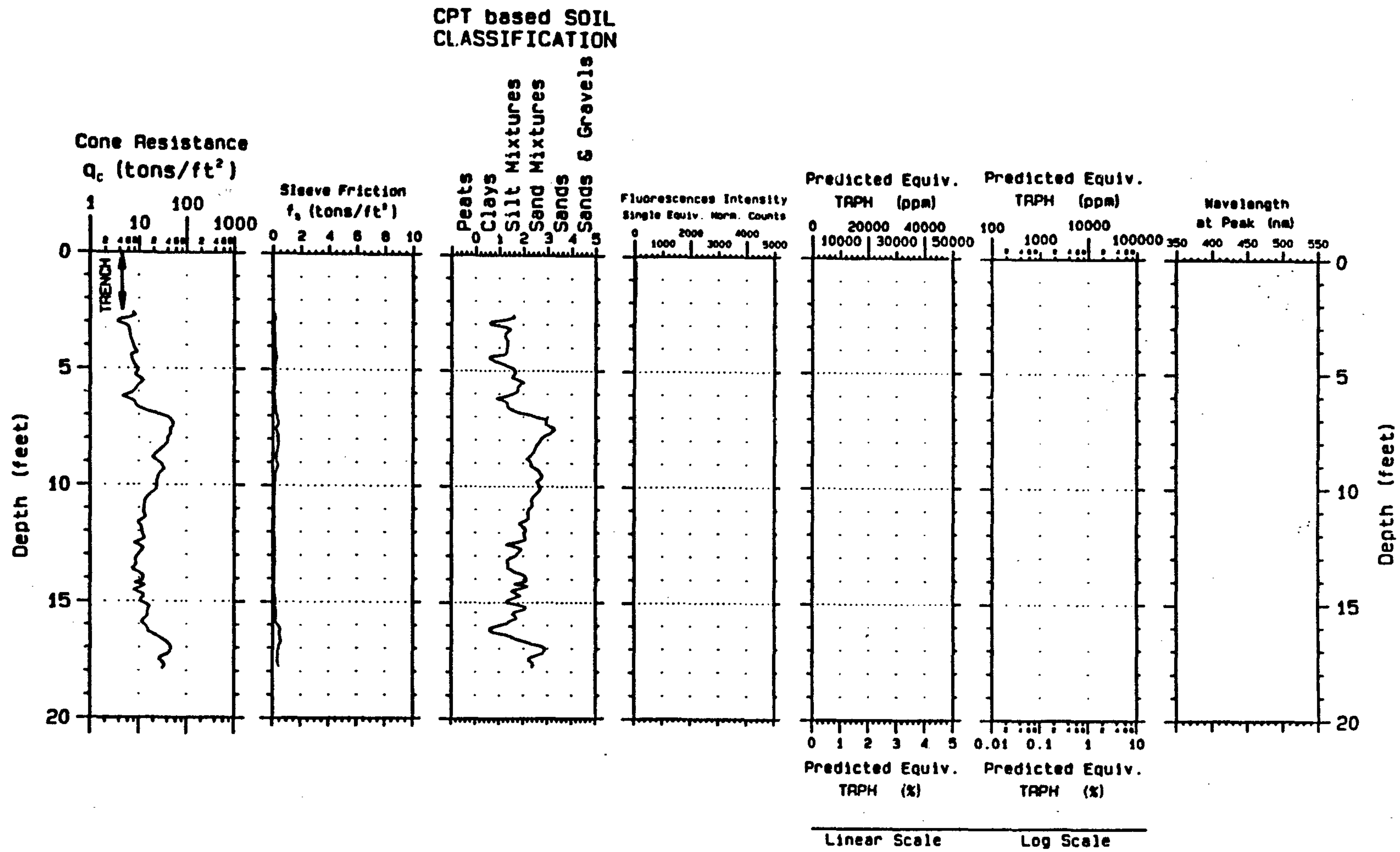
43. The results of cone penetrometer work performed in this area are shown in Figures 23-35. Figures 23-33 are the two dimensional plots of the data and Figures 34 and 35 are the three dimensional volumetric representations. There were a total of 11 holes pushed in this area. The results are also summarized and presented in Table 1. The first push attempted in this area resulted in a broken probe. The location was trenched to a depth of 1.5 ft to remove the pavement and underlying ballast, the hole was pushed to a depth of 3.5 ft at which point the probe struck a large boulder and broke. Therefore, only data



CPT: CF-WE-01 Project: Philadelphia Naval Shipyard <NEW>
STATE COORDINATES:
EASTING (ft.) NORTHING (ft.)

1 foot = 0.3048 meters
1 ton/ft^2 = 0.958 bars

Figure 23. Results of probe 1 at the Wharf E site.

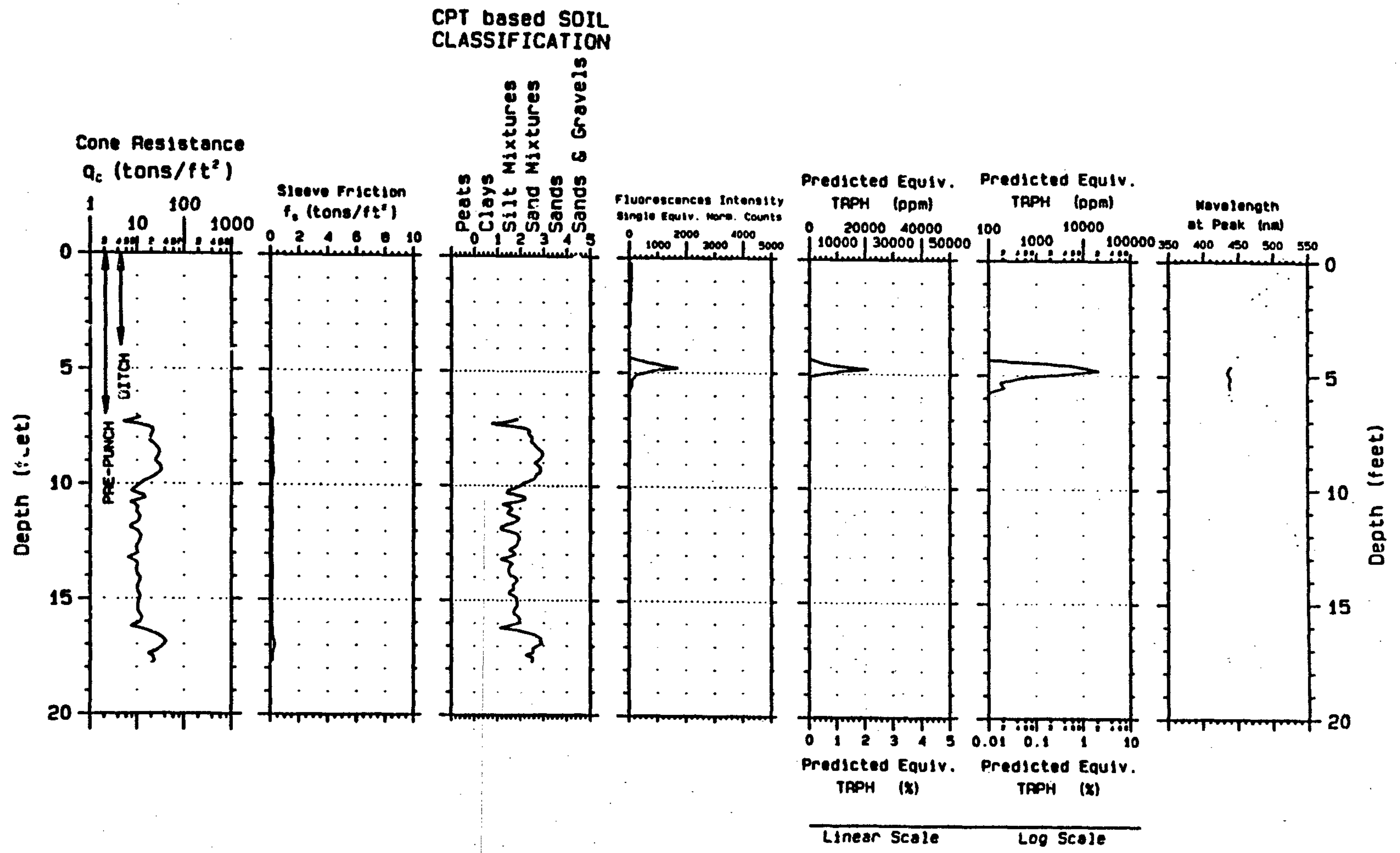


CPT: CP-WE-02
STATE COORDINATES:
EASTING (ft.) 2719126
NORTHING (ft.) 213944

Project: Philadelphia Naval Shipyard

1 foot = 0.3048 meters
1 ton/ft² = 0.958 bars

Figure 24. Results of probe 2 at the Wharf E site.



CPT: CP-WE-03

STATE COORDINATES:

EASTING (ft.) 2719116

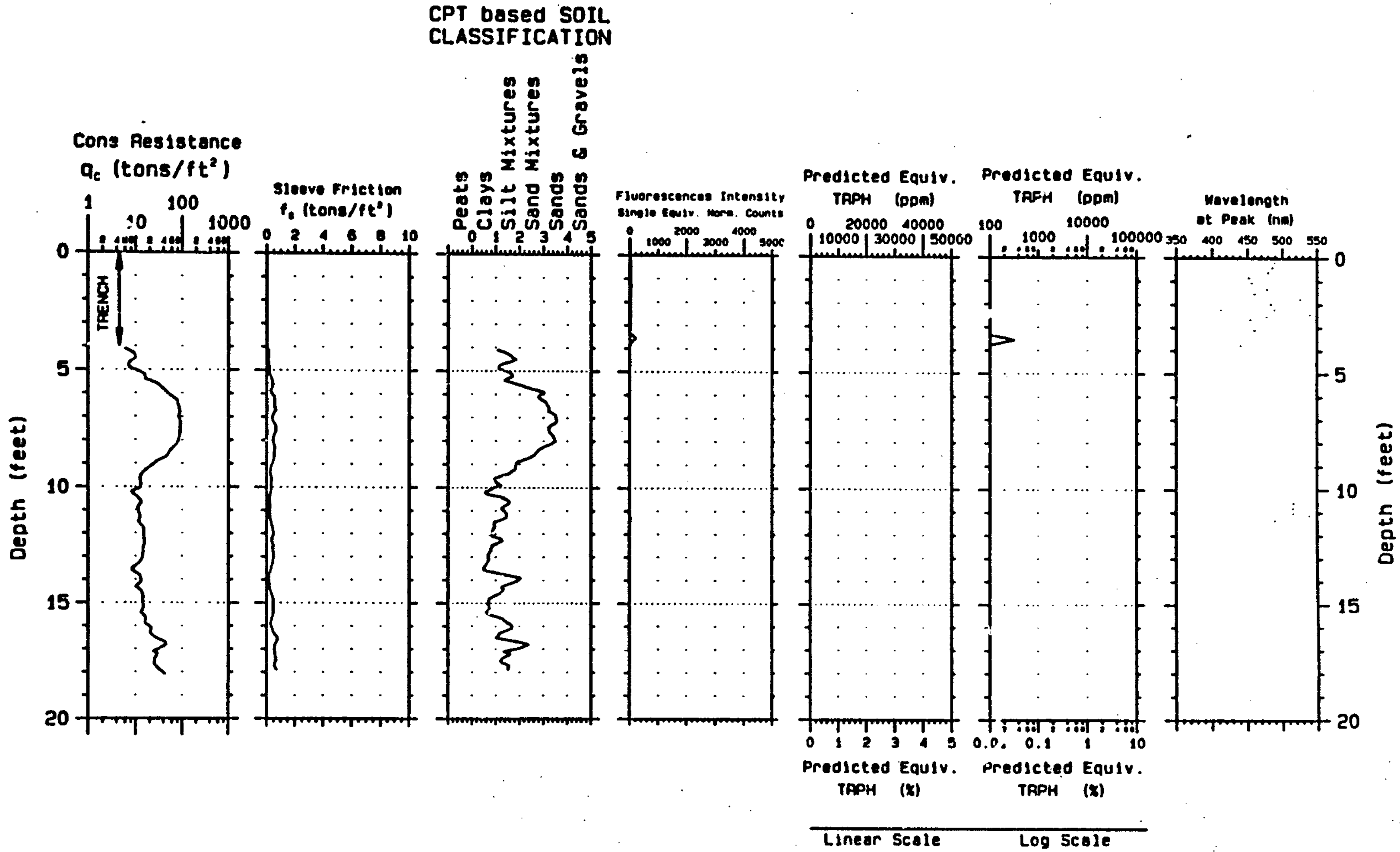
NORTHING (ft.) 213965

Project: Philadelphia Naval Shipyard

1 foot = 0.3048 meters

1 ton/ft² = 0.958 bars

Figure 25. Results of probe 3 at the Wharf E site.



CPT: CP-WE-04 Project: Philadelphia Naval Shipyard

STATE COORDINATES:

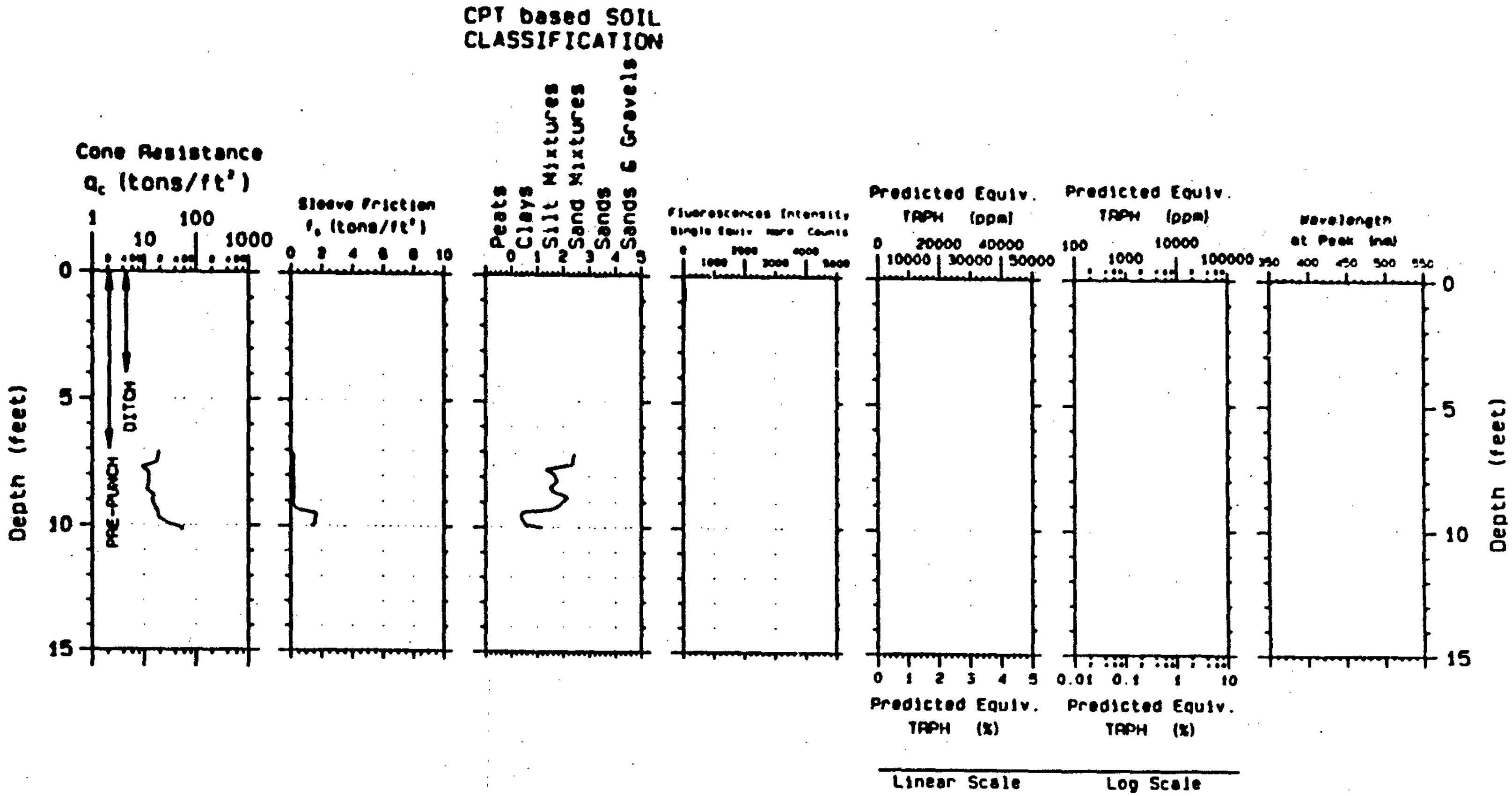
EASTING (ft.) 2719141

NORTHING (ft.) 213896

1 foot = 0.3048 meters

1 ton/ft^2 = 0.958 bars

Figure 26. Results of probe 4 at the Wharf E site.



CPT: CP-WE-05 Project: Philadelphia Naval Shipyard

STATE COORDINATES:

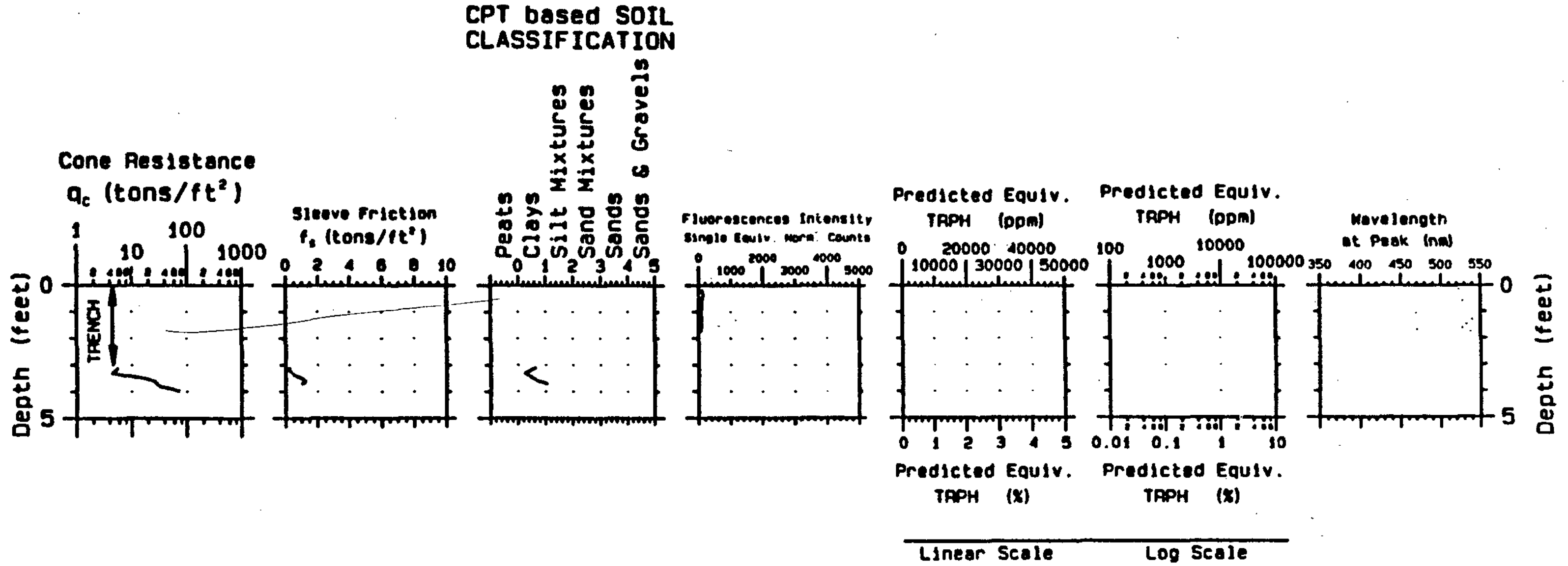
EASTING (ft.) 2719224

NORTHING (ft.) 213937

1 foot = 0.3048 meters

1 ton/ft² = 0.958 bars

Figure 27. Results of probe 5 at the Wharf E site.

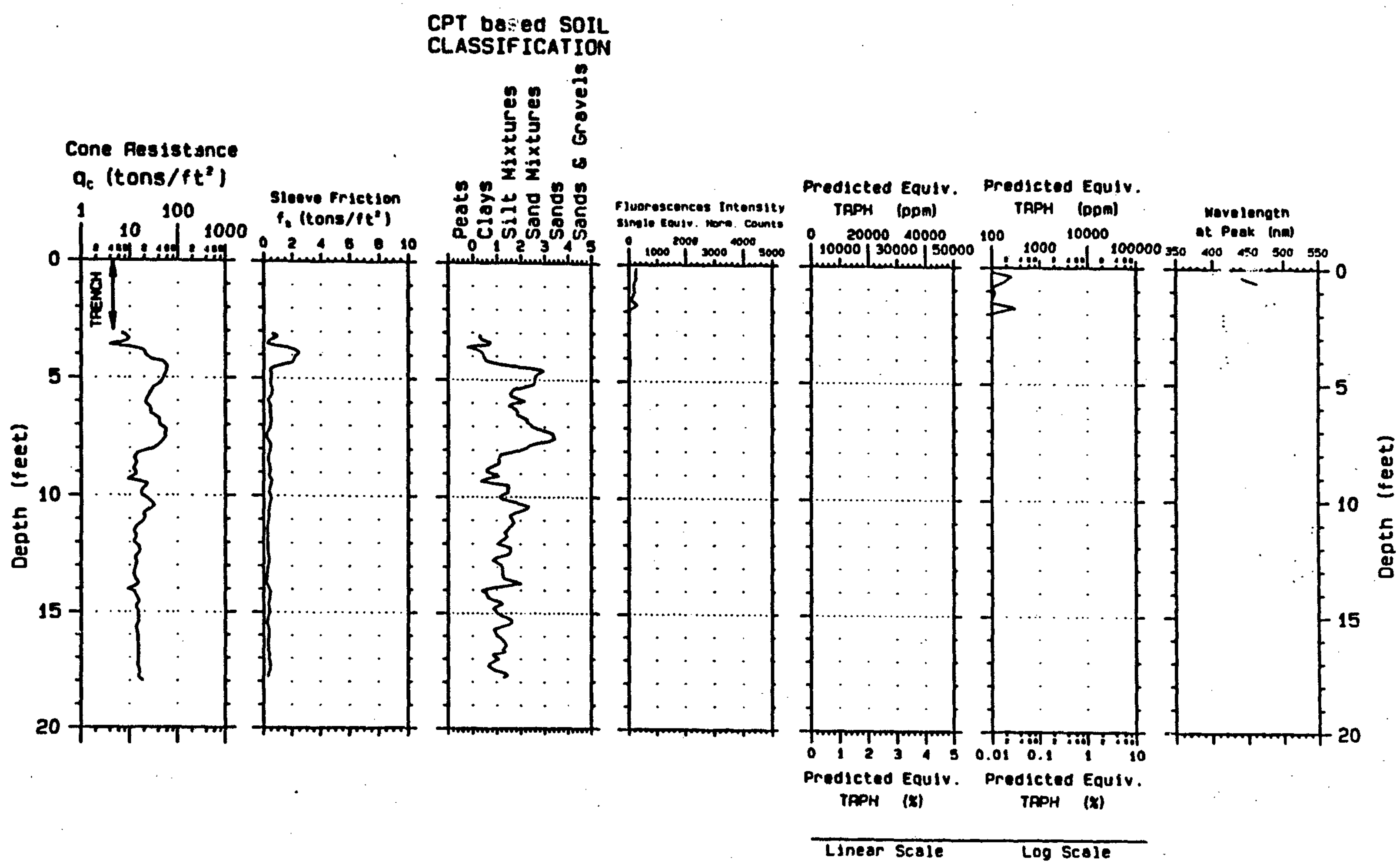


CPT: CP-WE-06 Project: Philadelphia Naval Shipyard

STATE COORDINATES:
EASTING (ft.) 2718890
NORTHING (ft.) 214038

1 foot = 0.3048 meters
1 ton/ft^2 = 0.958 bars

Figure 28. Results of probe 6 at the Wharf E site.



CPT: CP-WE-07

Project: Philadelphia Naval Shipyard

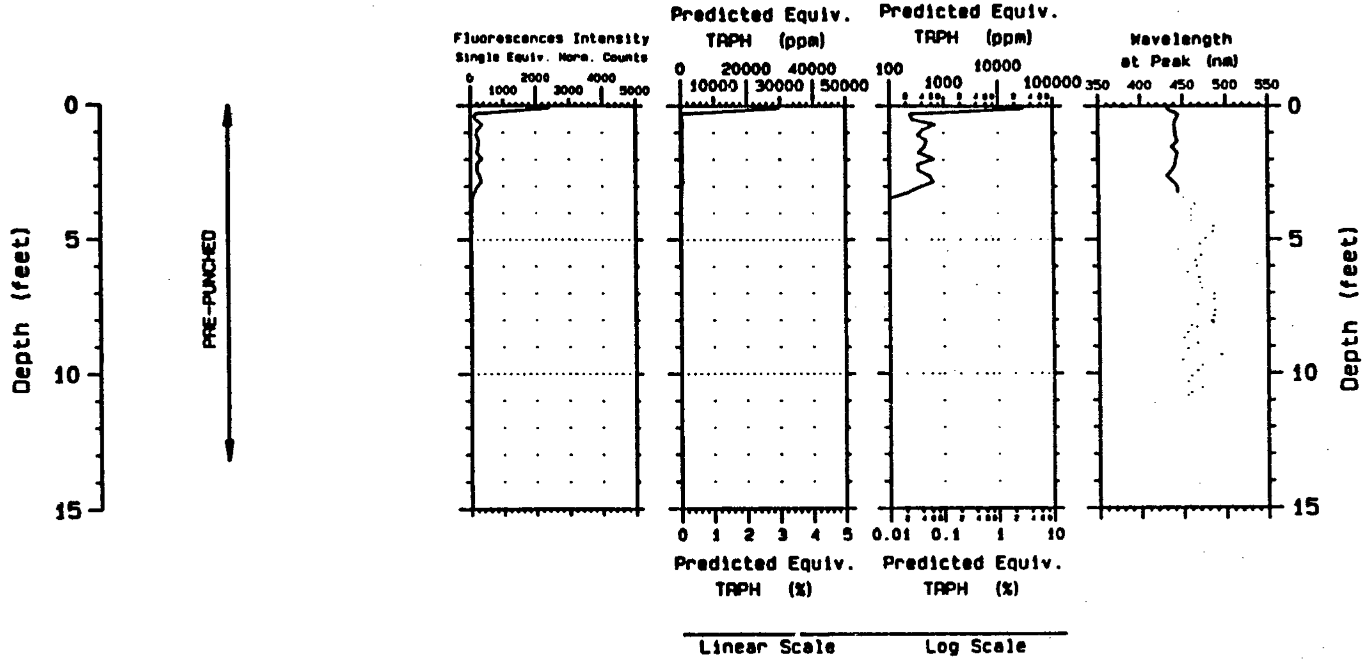
STATE COORDINATES:

EASTING (ft.) 2718890

NORTHING (ft.) 214038

1 foot = 0.3048 meters
1 ton/ft² = 0.958 bars

Figure 29. Results of probe 7 at the Wharf E site.

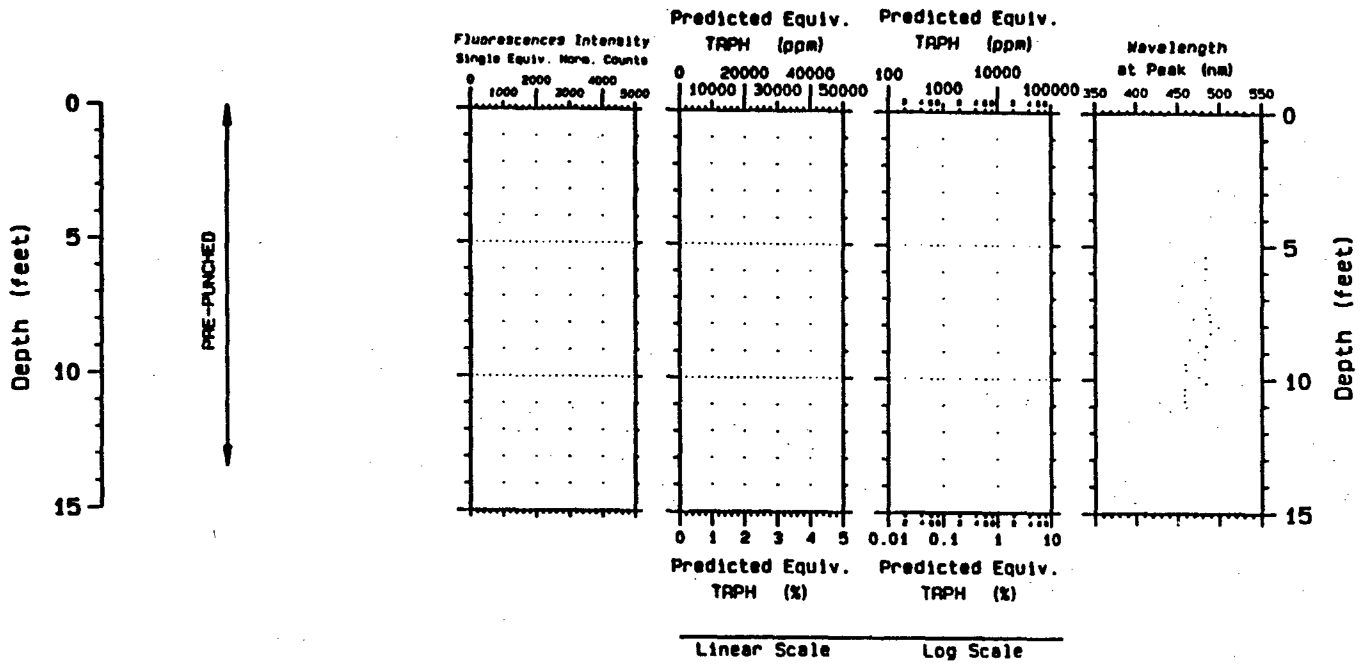


CPT: CP-WE-08
STATE COORDINATES:
EASTING (ft.) 2719082
NORTHING (ft.) 214004

Project: Philadelphia Naval Shipyard

1 foot = 0.3048 meters
1 ton/ft² = 0.958 bars

Figure 30. Results of probe 8 at the Wharf E site.



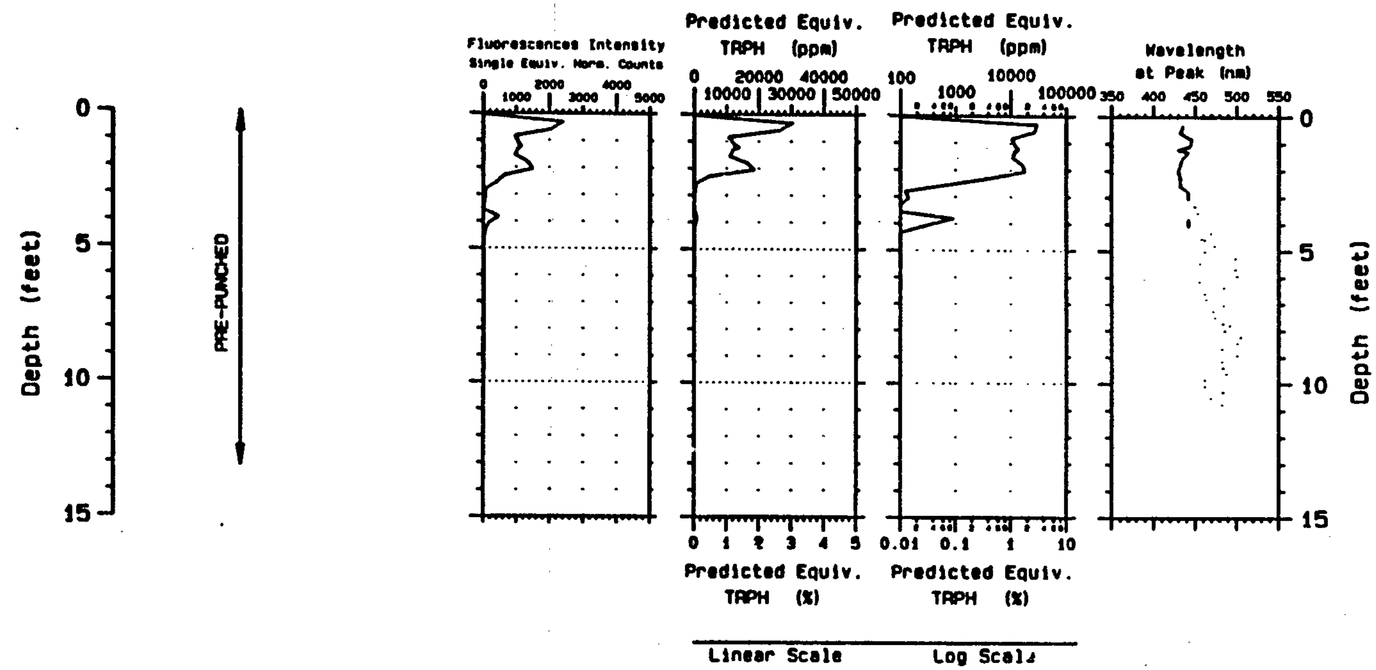
CPT: CP-WE-09 Project: Philadelphia Naval Shipyard

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)
2719025	214037

1 foot = 0.3048 meters
1 ton/ft² = 0.958 bars

Figure 31. Results of probe 9 at the Wharf E site.



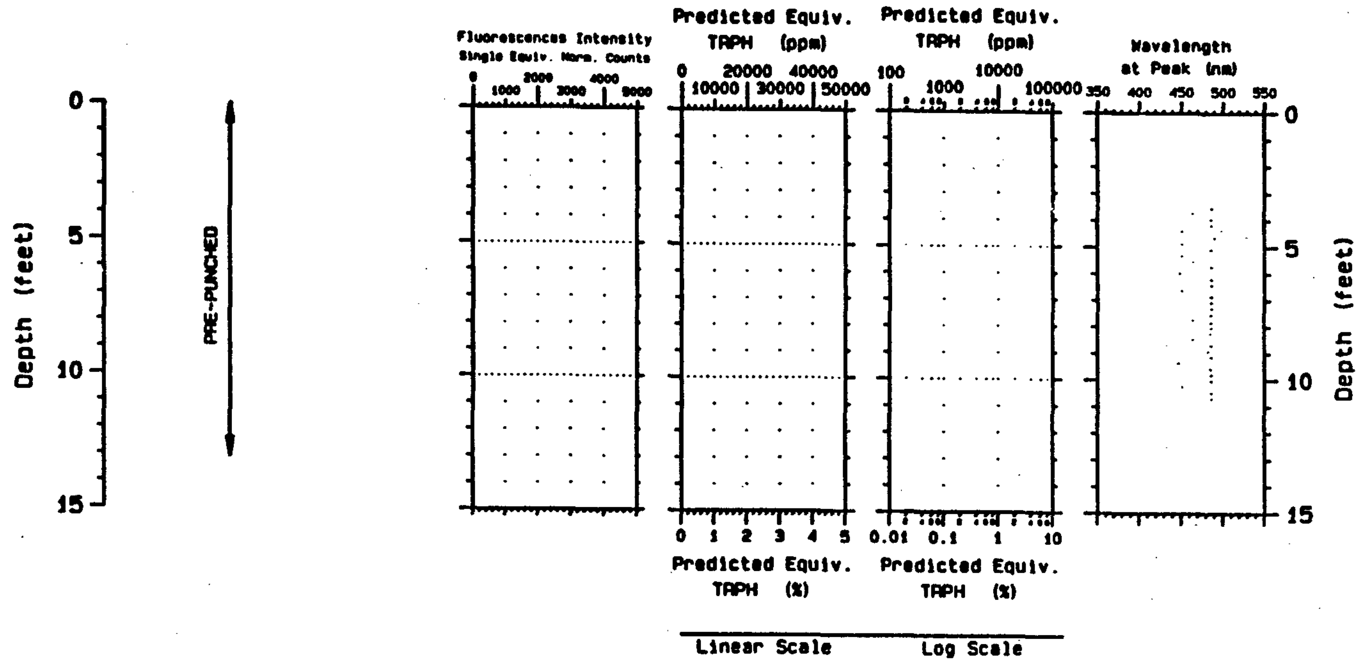
CPT: CP-WE-10 Project: Philadelphia Naval Shipyard

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)
2719127	214026

1 foot = 0.3048 meters
1 ton/ft² = 0.958 bars

Figure 32. Results of probe 10 at the Wharf E site.



CPT: CP-WE-11
STATE COORDINATES:
EASTING (ft.) 2719049
NORTHING (ft.) 214073

Project: Philadelphia Naval Shipyard

1 foot = 0.3048 meters
1 ton/ft² = 0.958 bars

Figure 33. Results of probe 11 at the Wharf E site.

recorded between a depth of 1.5 ft and 3.5 ft is shown in Figure 23. The high values seen on the cone resistance and sleeve friction panels are an indication of the boulder filled area. There was no meaningful fluorescence data obtained from this probe. The second probe was trenched slightly deeper (2.5 ft) before attempting to push in an effort to get below the zone of boulders. All the counts of fluorescence intensity were below the minimum resolution line. Push three was trenched to a depth of 4 ft and pre-punched to a depth of 7 ft. It is clearly seen from this figure that the pre-punching did not hinder the fluorescence data. A small amount of product is seen at a depth of 5 ft. The wavelength associated with this peak is approximately 440 nm, probably associated with some type diesel fuel. Probe four was trenched to a depth of 4 ft and showed very little return from the fluorimeter. A small hit was observed at a depth of 3.5 ft which is attributable to the laser firing into the open pit. Probe five was trenched to a depth of 4 ft and pre-punched to a depth of 7 ft. The only returns from the system were shallow near surface where the laser was firing into the open pit. Push six encountered a very hard object at 4 ft, at which point the push was terminated. No useful data was obtained from this probe. The seventh push was trenched to a depth of 3 ft with no pre-pushing, and showed only surface effects.

44. Probes eight through eleven were all conducted inside the excavated area, and were all pre-punched for the entire depth of investigation. Throughout the area, during excavation, samples were taken at depths of 2.5 ft and 5 ft. CPT probes were located in areas that had shown large amounts of product (probes 8,10-11) and in an area that had shown no product (probe 9). The area was excavated to a depth of 5 ft, therefore the pushes were stopped after pushing 13 ft in order to stay at the agreed maximum depth of investigation of 18 ft. Probe eight encountered product from the start of the push to a depth of 4 ft (9 ft from the original ground surface). Here again the wavelength is approximately 440 nm. Probe nine was located in an area where samples revealed no product and this was verified by the fluorometer. Push ten showed large amounts of product from the start of the probe to a depth of 3 ft. The wavelength ranges between 430 and 445 nm. Push eleven did not reveal any product in the soil. The wavelengths encountered in this

area do not correspond to those of any product tested from the PNSY. This could be an indication that the products are severely oxidized or possibly that mixing of different products has occurred.

Table 1. Summary of results for the Wharf E site.

PROBE NAME	DEPTH INVESTIGATED (FROM GROUND SURFACE)	PRODUCT ENCOUNTERED	POSSIBLE PRODUCT
CP-WE-01	1.5 - 4 ft	no	NA
CP-WE-02	2.5 - 18 ft	no	NA
CP-WE-03	4 - 18 ft	yes; 4-5.5 ft	Fuel oil
CP-WE-04	4 - 18 ft	no	NA
CP-WE-05	4 - 10 ft	no	NA
CP-WE-06	3 - 4 ft	no	NA
CP-WE-07	3 - 18 ft	no	NA
CP-WE-08	5 - 18 ft	yes; 5-8.5 ft	Fuel oil
CP-WE-09	5 - 18 ft	no	Na
CP-WE-10	5 - 18 ft	yes; 5-8 ft	Fuel oil
CP-WE-11	5 - 18 ft	no	NA

45. The results of the three dimensional representations of the data for this site are shown in Figures 34 and 35. Each figure contains a color legend showing the color and corresponding counts for each isosurface. The location of each probe is also shown in the form of a gray line. In Figure 34 the results are displayed for concentrations above 100 ppm, which encompasses all the meaningful data at the site. The view displayed is looking south to north. The majority of the data for the site is obtained from the excavated pit centering around probes CP-WE-8 and CP-WE-10. Figure 35 shows the concentrations of 300 ppm and above. The view is again looking south to north.

Wharf G Results

46. A total of six pushes were accomplished at this site, shown in two

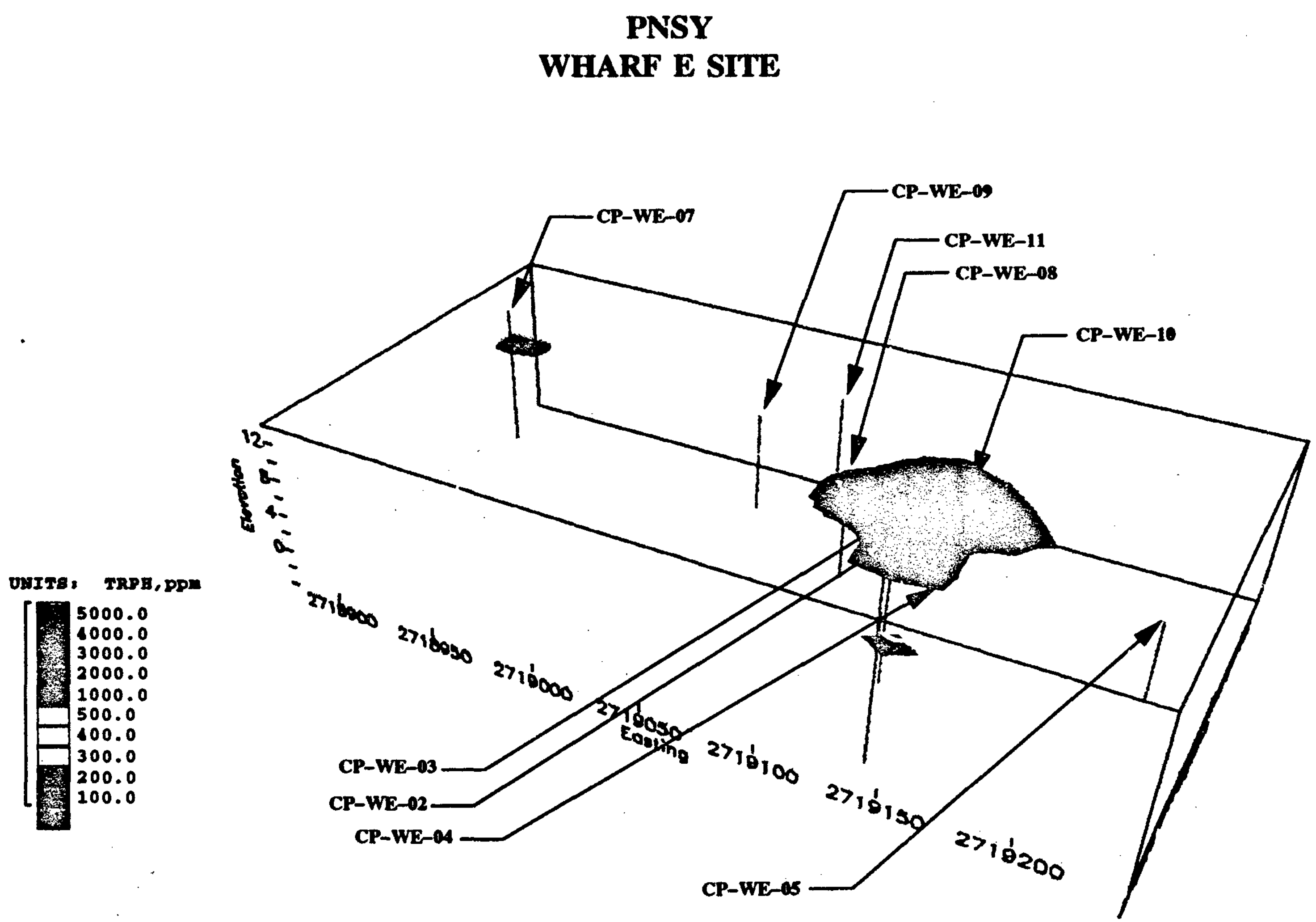


Figure 34. Volumetric representation of Wharf E results showing TRPH above 100 ppm.

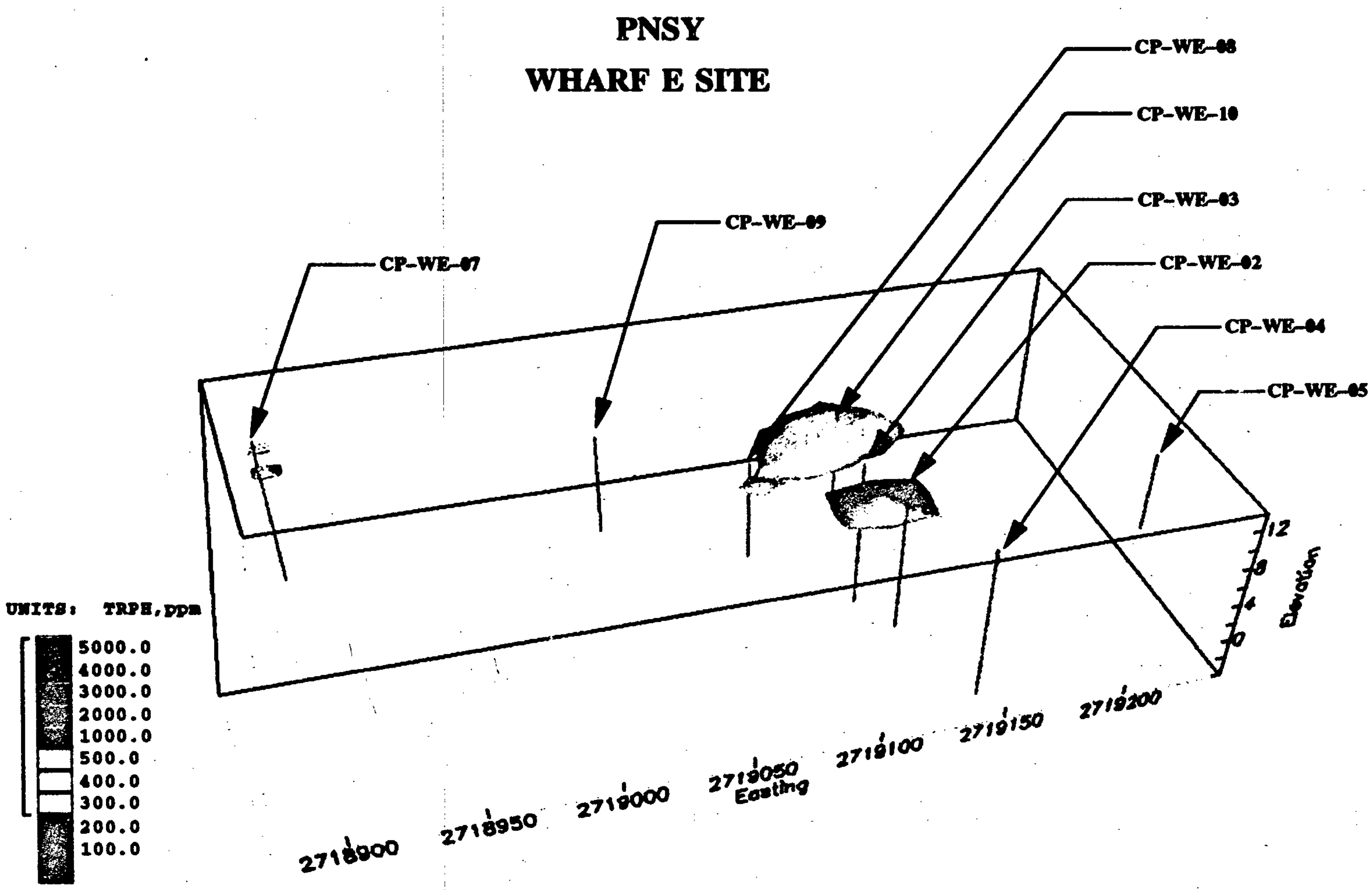
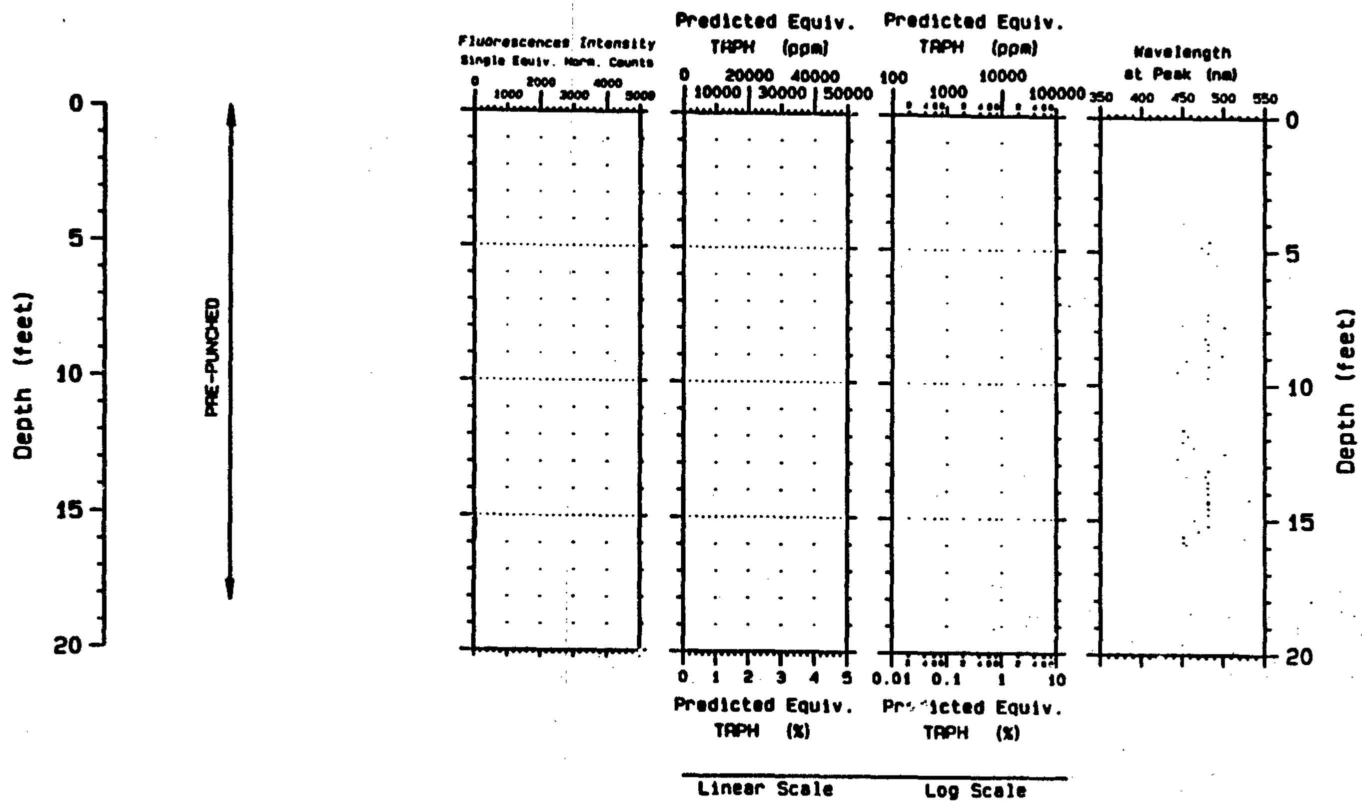


Figure 35. Volumetric representation of Wharf E results showing all TRPH with a section sliced away to reveal TRPH above 300 ppm for area centered around probe CP-WE-10.

dimensional form in Figures 36-41, and in three dimensional form in Figures 42-46. The results of each push are discussed following and summarized in Table 2. All probes in this area were pre-pushed for the entire depth of investigation, resulting in no soil property data. The first push had all counts well below minimum resolution and revealed no contaminants in the soil. Push two encountered a very large amount of product between depths of 5 to 12 ft. This probe was very near a monitoring well that had been sampled and analyzed with the results pointing to high concentrations of diesel fuel. The recording instrument was set for maximum peak counts of 10000, which was exceeded at a depth of 8 ft effectively saturating the instrument. There was more product encountered in this hole than any other at the site, and also required more grout to seal than any other hole. The wavelength, other than where the instrument saturated, is approximately 440 to 450 nm. The third push also showed considerable amounts of product between the depths of 2.5 and 11 ft. The wavelengths through the region shows some variation but would be an approximate average of 440 nm. The fourth push showed very small traces of product at 1 ft and 10 ft. Push five showed product just beneath the surface, at a depth of 1.5 ft, and between depths of 6 to 11 ft. The associated wavelength is between 440 and 455 nm. Push six revealed considerable product between depths of 5 and 15 ft with a wavelength of approximately 450 nm.

Table 2. Summary of results for the Wharf G site.

PROBE NAME	DEPTH INVESTIGATED (FROM GROUND SURFACE)	PRODUCT ENCOUNTERED	POSSIBLE PRODUCT
CP-WG-01	0 - 18 ft	no	NA
CP-WG-02	0 - 18 ft	yes; 5-12 ft	Fuel oil
CP-WG-03	0 - 18 ft	yes; 3-11 ft	Fuel oil
CP-WG-04	0 - 18 ft	yes; 1,10 ft	Fuel oil
CP-WG-05	0 - 18 ft	yes; 0-2 ft and 6-11 ft	Fuel oil
CP-WG-06	0 - 18 ft	yes; 6-15 ft	Fuel oil



CPT: CP-WG-01 Project: Philadelphia Naval Shipyard

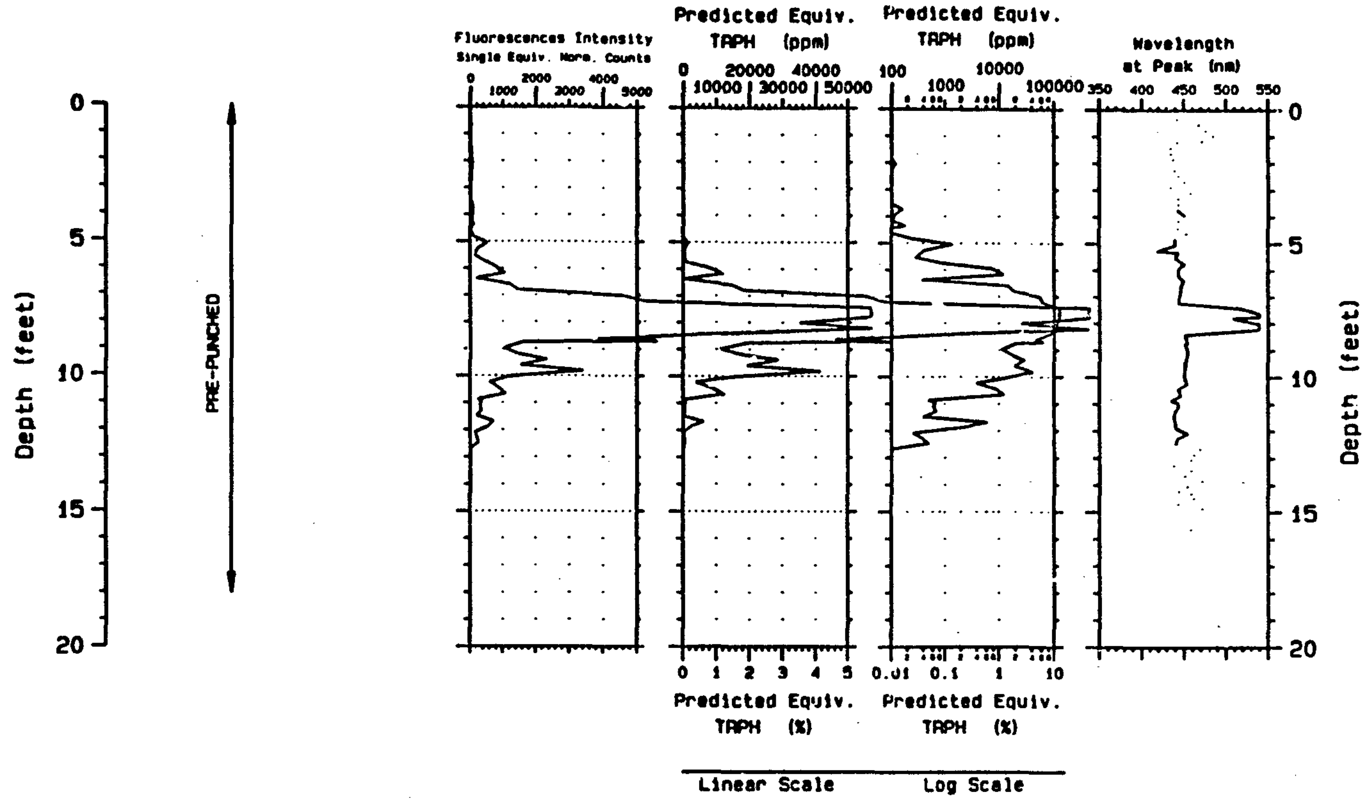
STATE COORDINATES:

EASTING (ft.) 2717542

NORTHING (ft.) 213745

1 foot = 0.3048 meters
1 ton/ft² = 0.958 bars

Figure 36. Results of probe 1 at the Wharf G site.

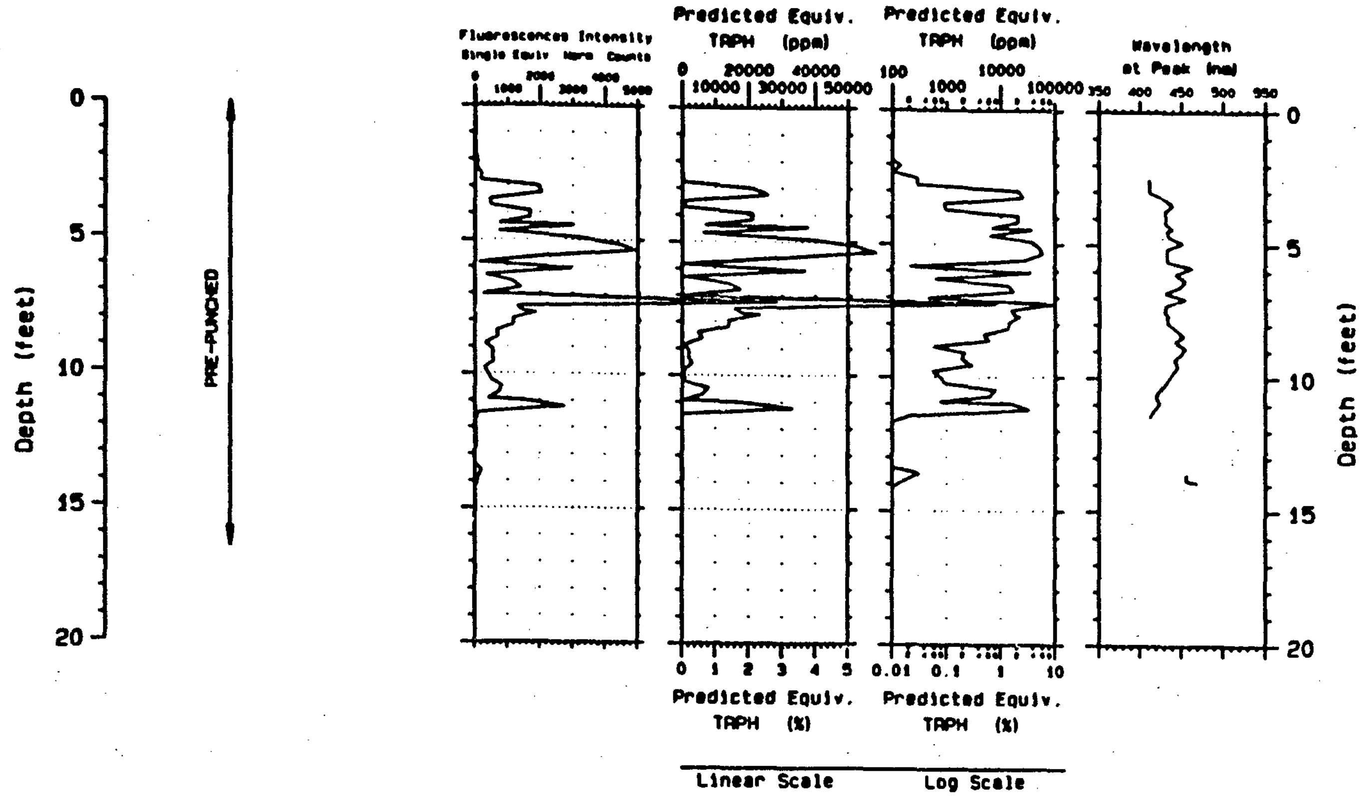


CPT: CP-WG-02
STATE COORDINATES:
EASTING (ft.) 2717517
NORTHING (ft.) 213805

Project: Philadelphia Naval Shipyard

1 foot = 0.3048 meters
1 ton/ft² = 0.958 bars

Figure 37. Results of probe 2 at the Wharf G site.



CPT: CP-WG-03 Project: Philadelphia Naval Shipyard

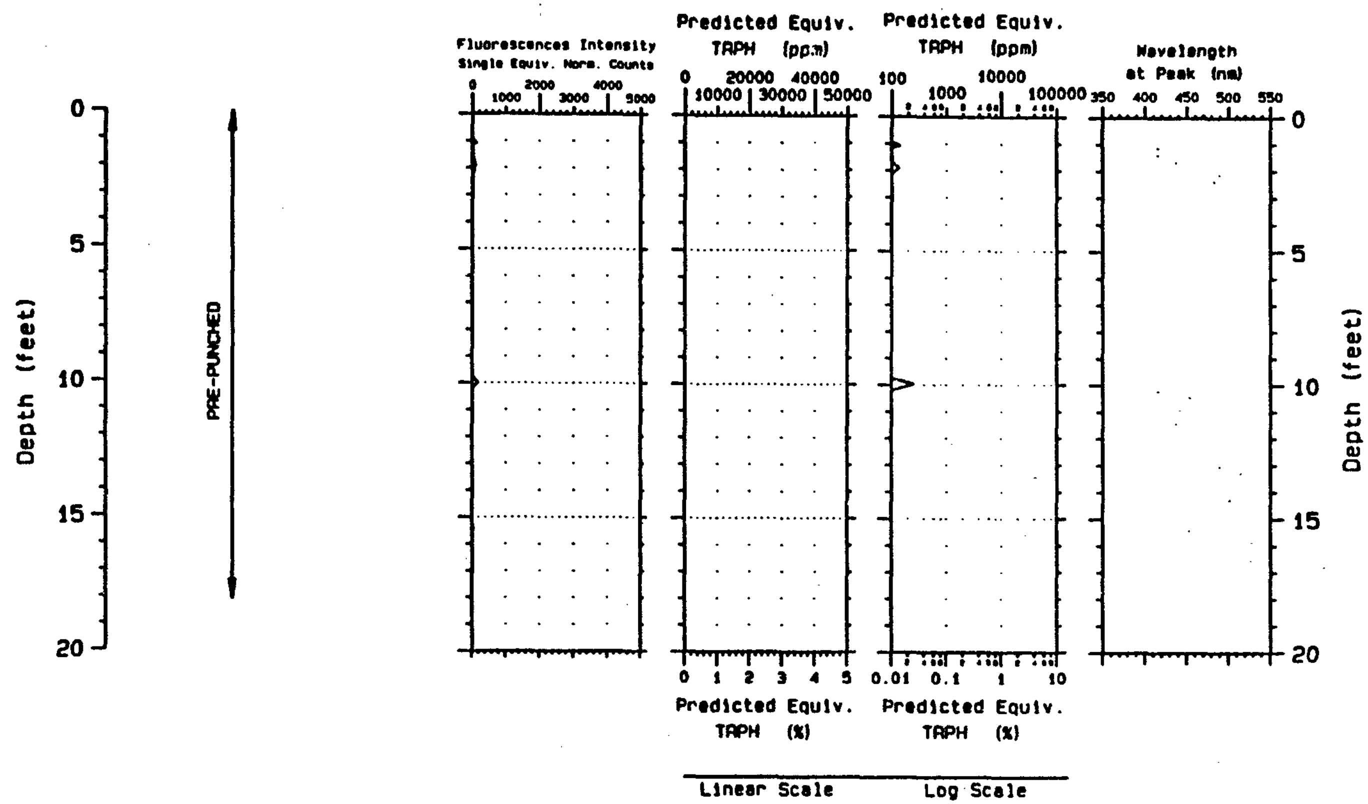
STATE COORDINATES:

EASTING (ft.) 2717557

NORTHING (ft.) 213803

1 foot = 0.3048 meters
1 ton/ft² = 0.958 bars

Figure 38. Results of probe 3 at the Wharf G site.



CPT: CP-WG-04 Project: Philadelphia Naval Shipyard

STATE COORDINATES:

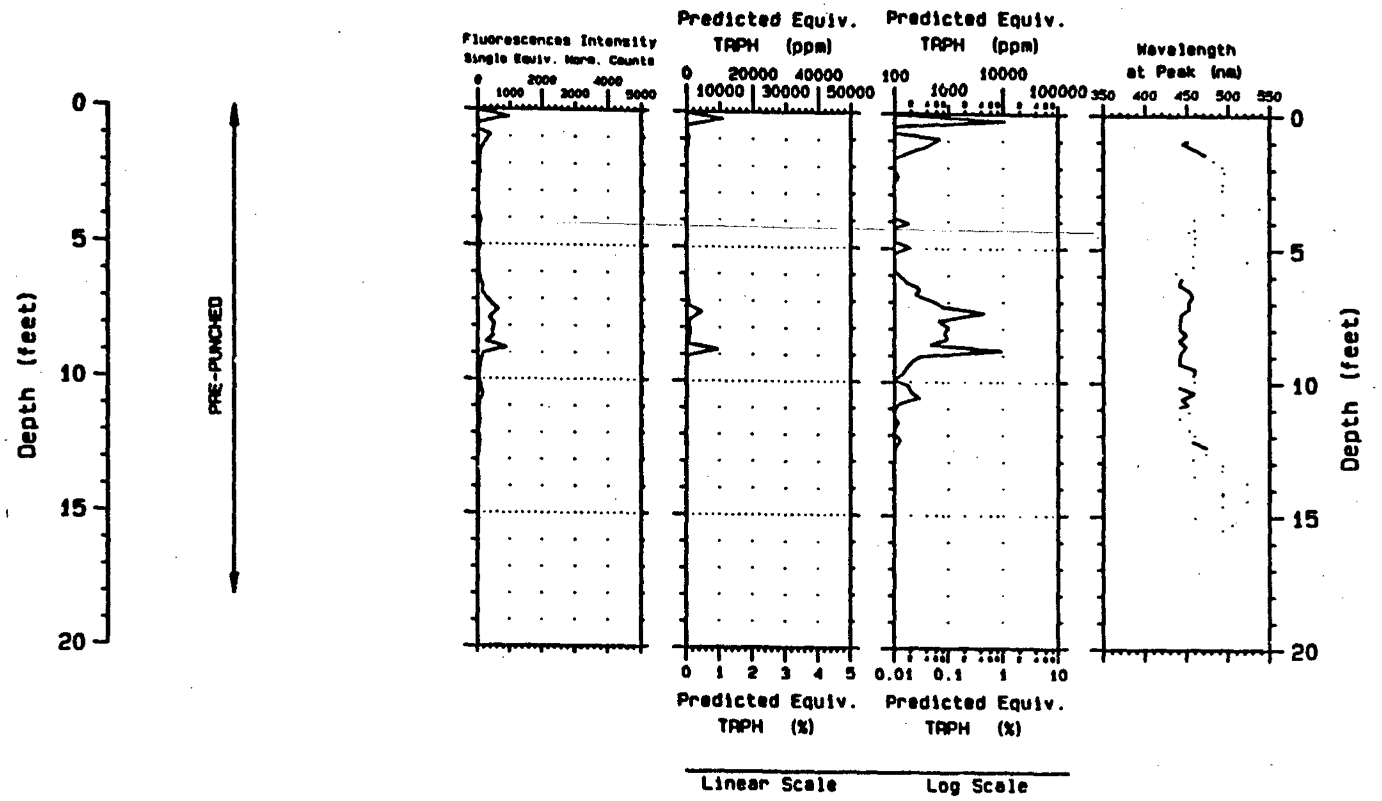
EASTING (ft.) NORTHING (ft.)

2717497 213760

1 foot = 0.3048 meters

1 ton/ft² = 0.958 bars

Figure 39. Results of probe 4 at the Wharf G site.

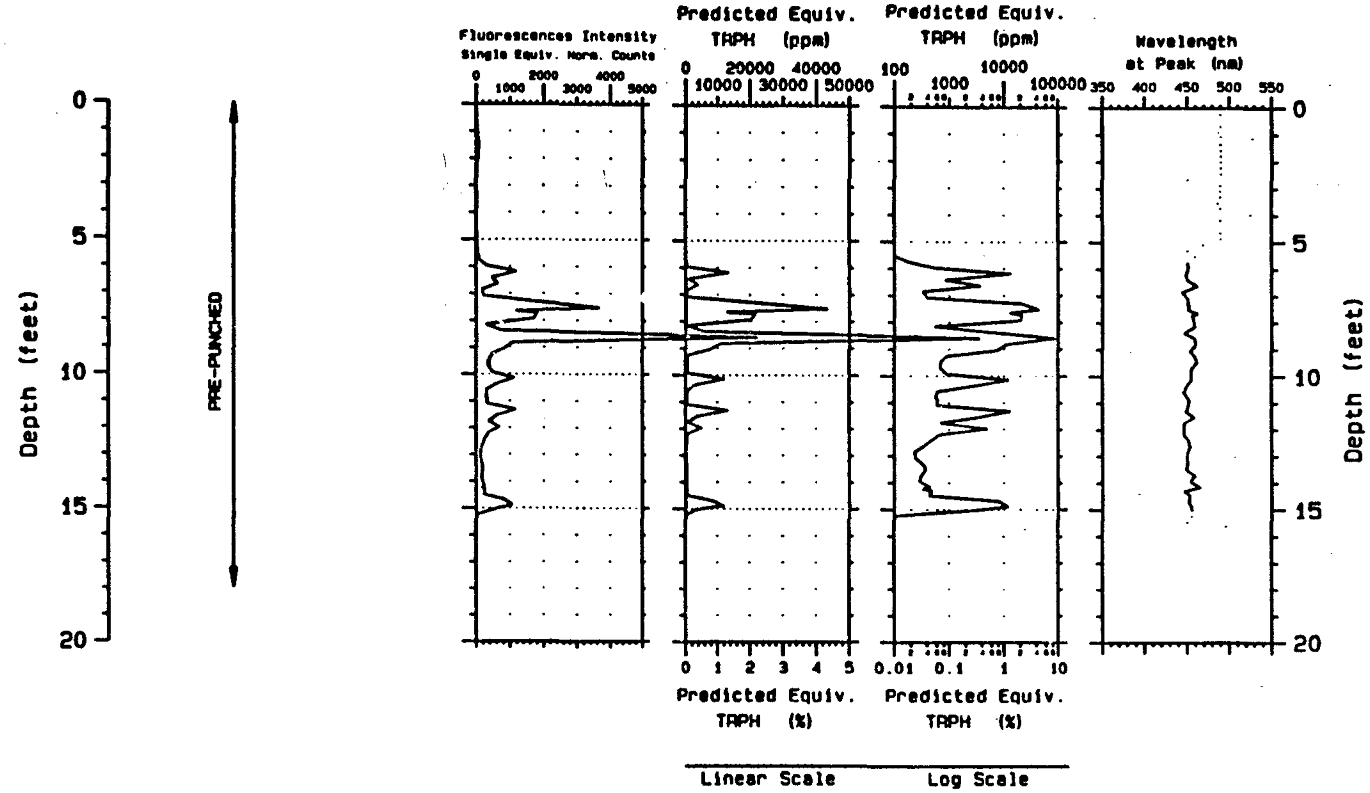


CPT: CP-WG-05
STATE COORDINATES:
EASTING (ft.) 2717506
NORTHING (ft.) 213794

Project: Philadelphia Naval Shipyard

1 foot = 0.3048 meters
1 ton/ft² = 0.958 bars

Figure 40. Results of probe 5 at the Wharf G site.



CPT: CP-WG-06 Project: Philadelphia Naval Shipyard

STATE COORDINATES:

EASTING (ft.) 2717533

NORTHING (ft.) 213853

1 foot = 0.3048 meters

1 ton/ft² = 0.958 bars

Figure 41. Results of probe 6 at the Wharf G site.

47. The results of the three dimensional representations of data from this site are shown in Figures 42-46. Figure 42 is looking southwest to northeast, and displays data with concentrations higher than 100 ppm. The majority of data in this area centered around the three underground storage tanks. The plume is most certainly spread out around the tanks, the exact shape could only be determined by more extensive probing in the area. The shape shown is only conceptually based on the data collected. The same data are shown in Figure 43, only rotated to look west to east and not tilted. From this view, the vertical extent of the plume can be seen. Figure 44 is a view looking northwest to southeast. All the data for the site are displayed, however a chair cut has been placed in the data to reveal the contaminant plume of concentrations above 300 ppm. Figures 45 and 46 are more views of the plume, looking southwest to northeast, showing concentrations above 300 ppm and concentrations above 4000 ppm respectively.

DRMO Results

48. Four pushes were performed in this area with the two dimensional results shown in Figures 47-50 and the three dimensional results shown in Figures 51 and 52. The results of each push are discussed following and summarized in Table 3. The first push in this area was pre-punched to determine if any boulders were in the area with subsequent pushes not being pre-punched. During the first push, the sleeve was damaged and therefore no sleeve friction data are presented (time constraints did not allow fixing the sleeve before more pushes were made that day). Push one encountered product between depths of 5 to 7 ft. The wavelength associated with the peak curve is approximately 475 nm, very close to that of #6 fuel oil. The second push detected product between depths of 3 to 7 ft. Here again the peak curve corresponds closely to a wavelength associated with #6 fuel oil. The third push detected product between depths of 4 to 7 ft. The wavelength of the peak curve is approximately 470 nm. Moving progressively further away from the oil-water separator, push four encountered nothing above the minimum resolution of the SCAPS system.

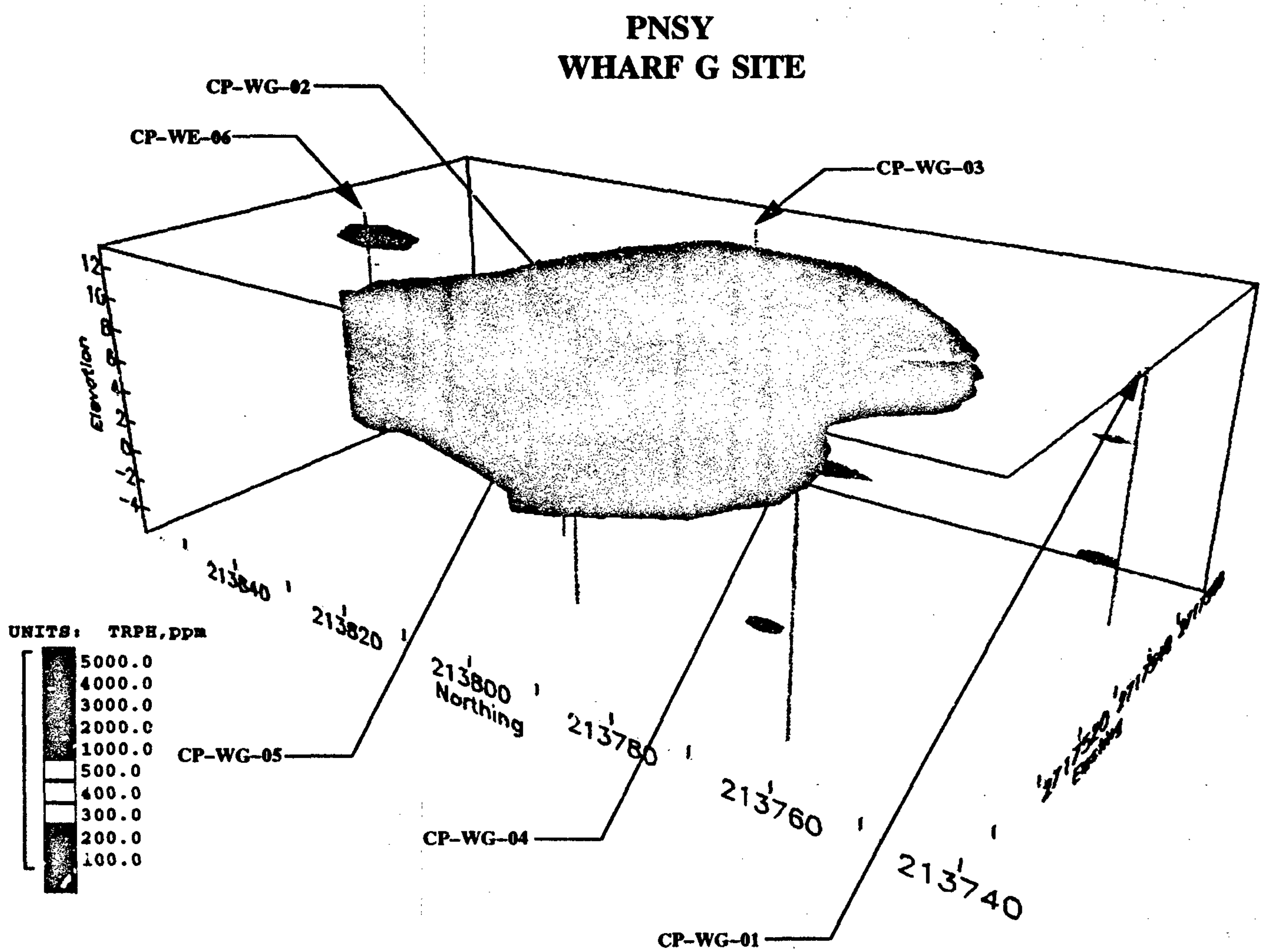


Figure 42. Volumetric representation of Wharf G results showing TRPH above 100 ppm.

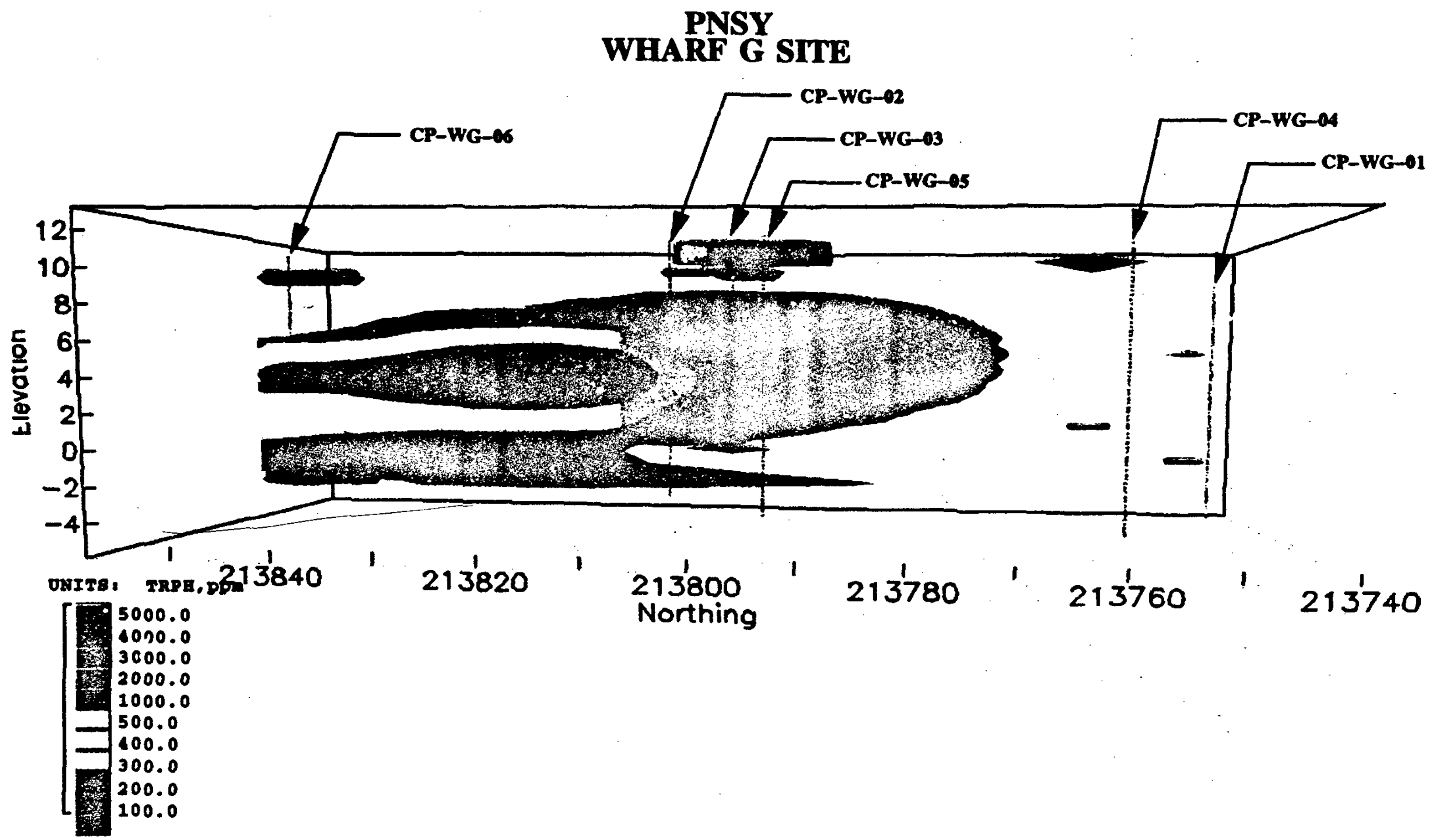


Figure 43. Volumetric representation of Wharf G results showing TRPH above 100 ppm, side view looking west to east.

PNSY
WHARF G SITE

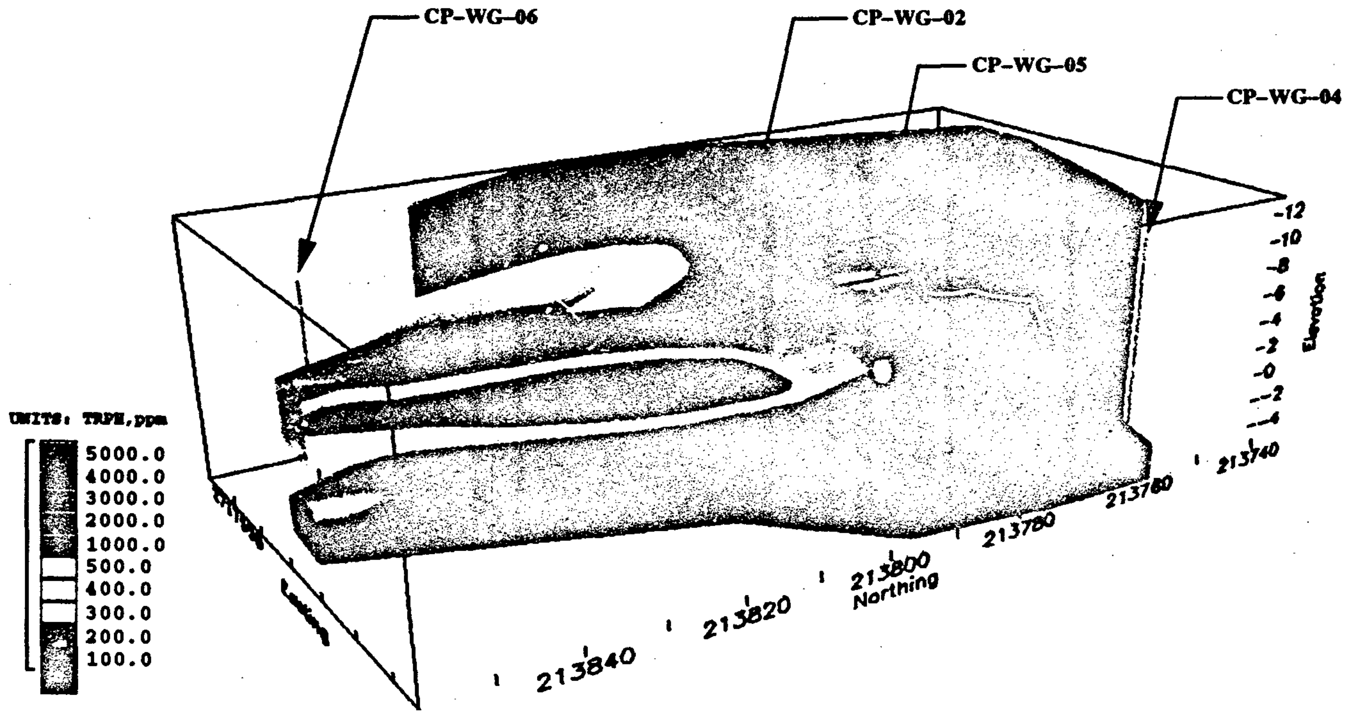


Figure 44. Volumetric representation of Wharf G results showing TRPH above 100 ppm with a section sliced away to reveal TRPH above 300 ppm.

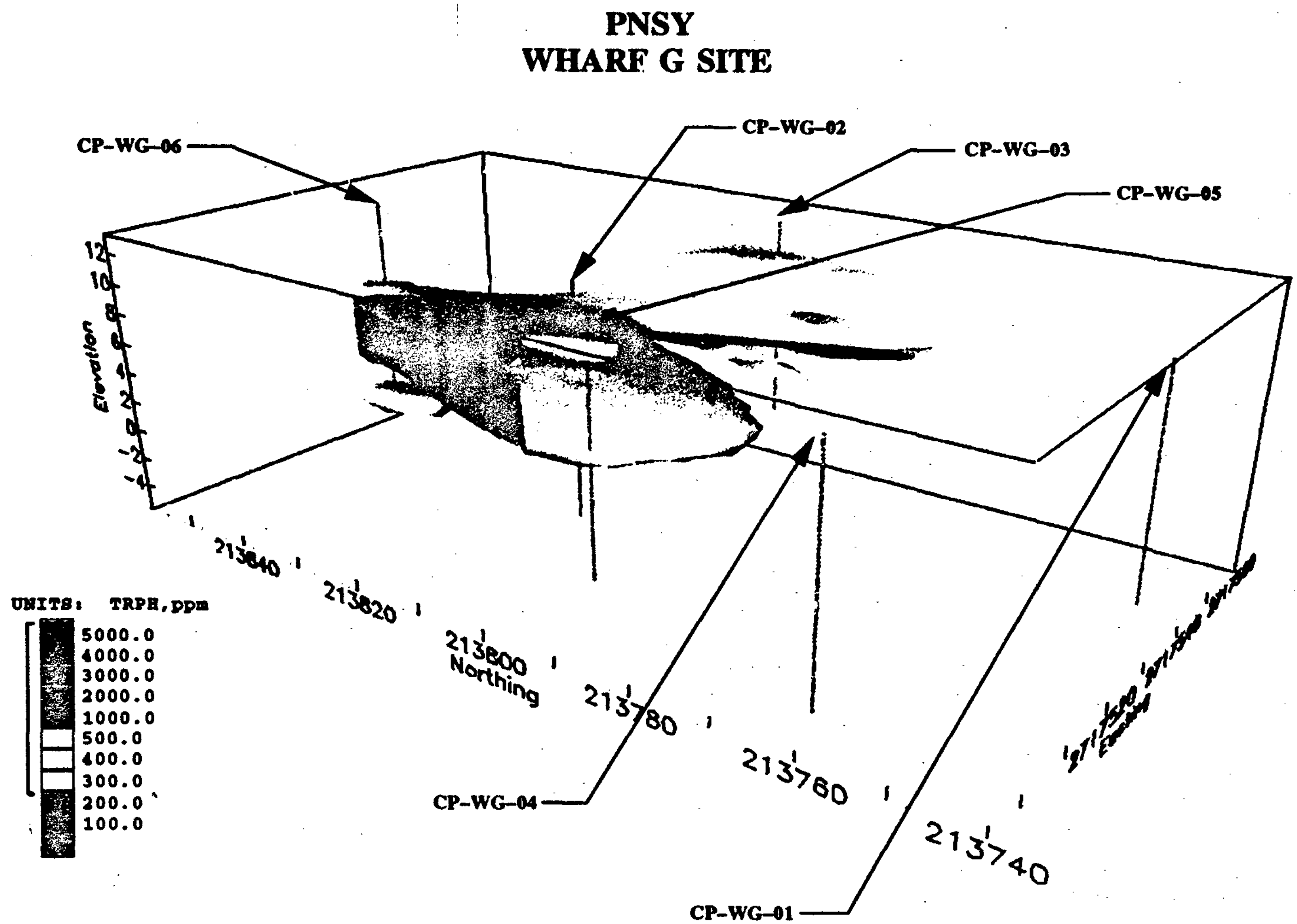


Figure 45. Volumetric representation of Wnarf G results showing TRPH above 300 ppm.

PNSY
WHARF G SITE

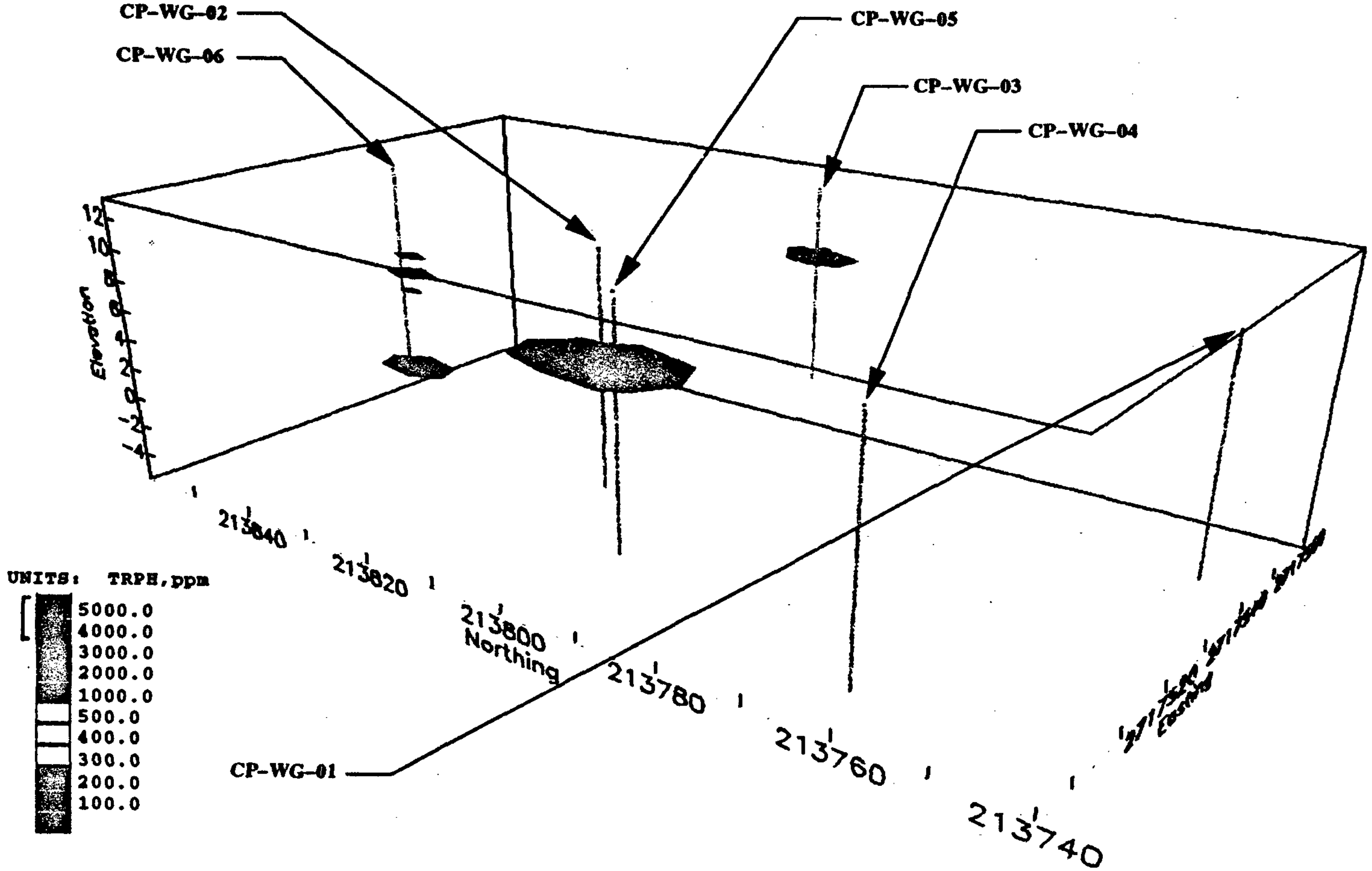
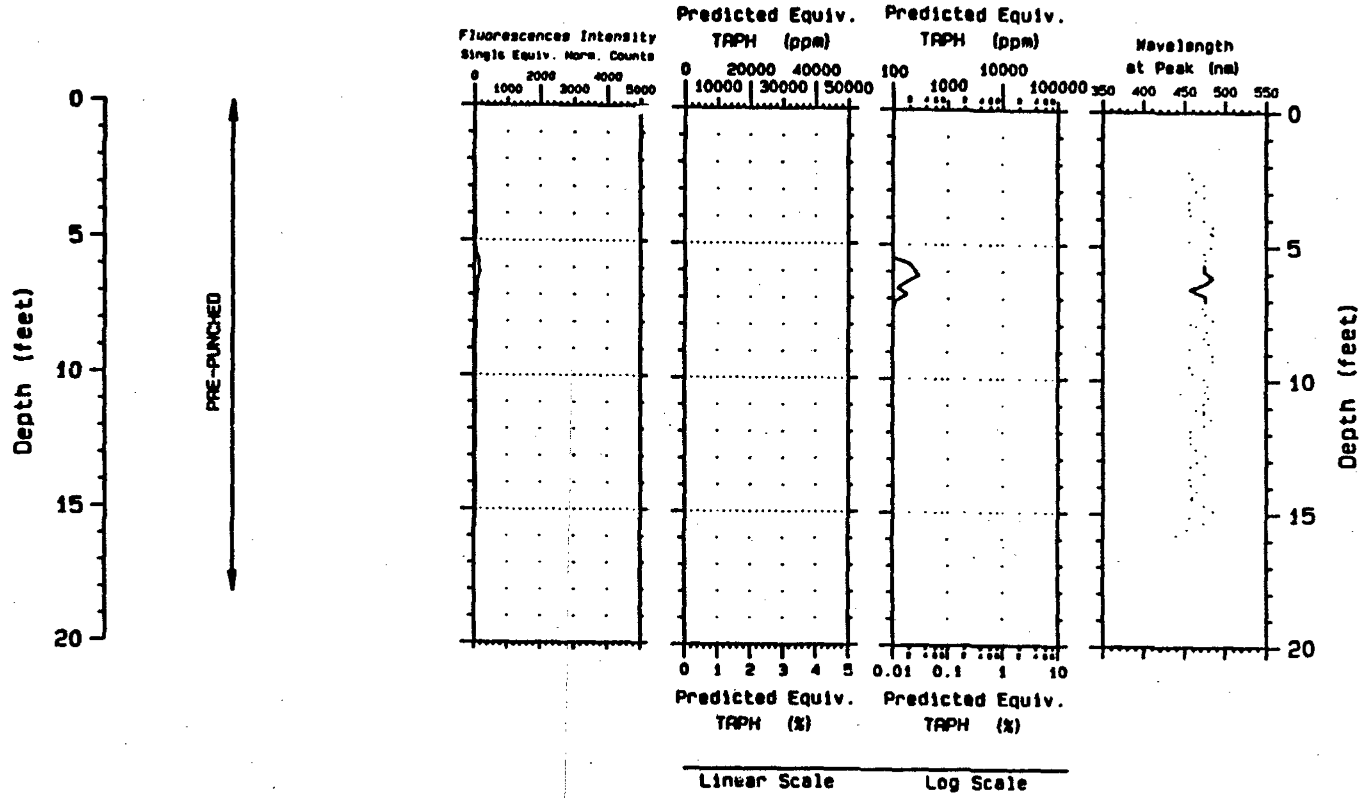


Figure 46. Volumetric representation of Wharf G results showing TRPH above 4000 ppm.



CPT: CP-DM-01

Project: Philadelphia Naval Shipyard

STATE COORDINATES:

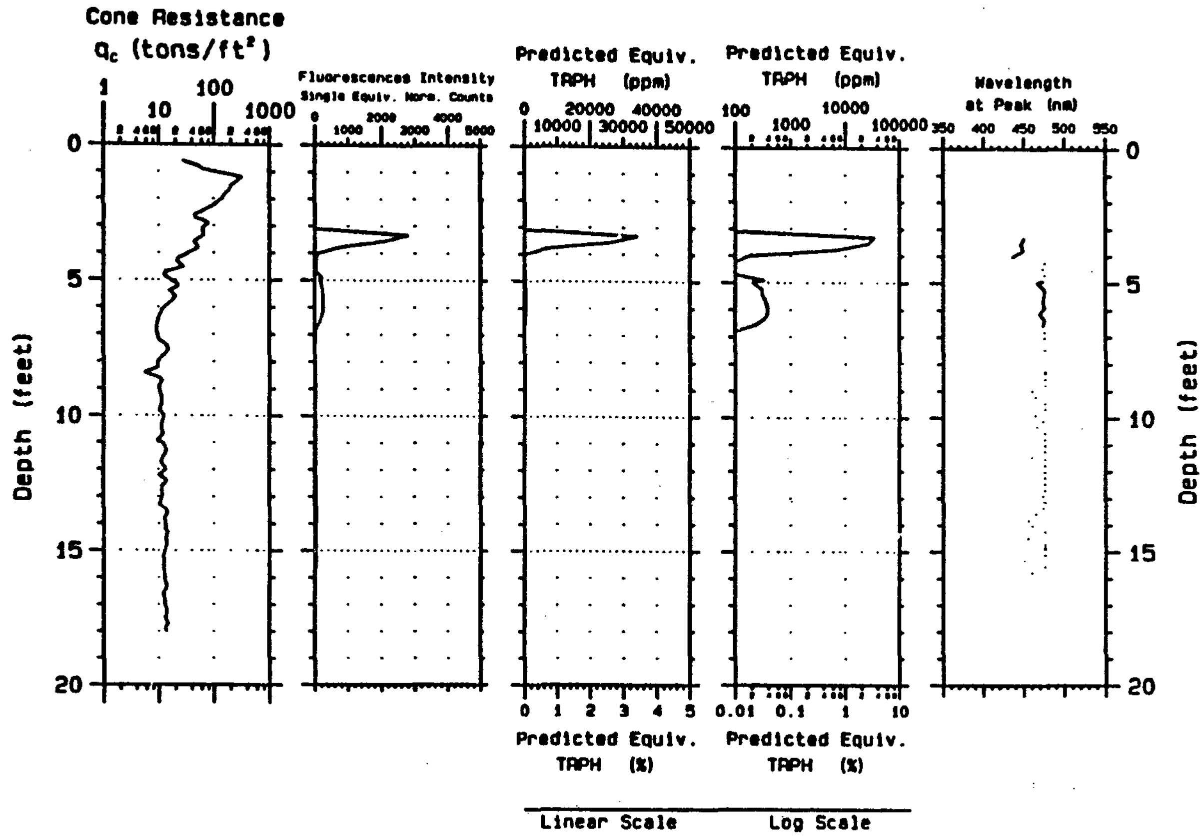
EASTING (ft.) 2716583

NORTHING (ft.) 216196

1 foot = 0.3048 meters

1 ton/ft² = 0.958 bars

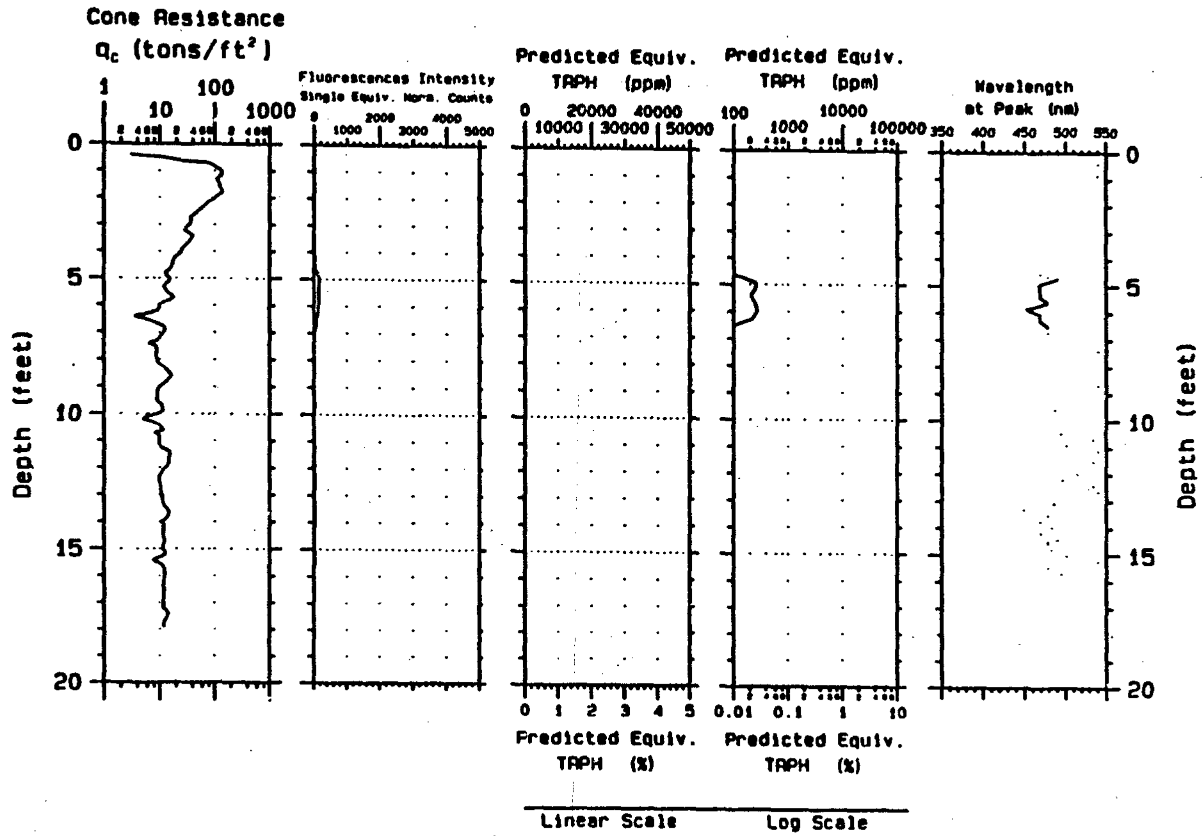
Figure 47. Results of probe 1 at the DRMO site.



CPT: CP-DM-02 Project: Philadelphia Naval Shipyard
STATE COORDINATES:
EASTING (ft.) NORTHING (ft.)
2716578 216249

1 foot = 0.3048 meters
1 ton/ft^2 = 0.958 bars

Figure 48. Results of probe 2 at the DRMO site.



CPT: CP-DM-03

Project: Philadelphia Naval Shipyard

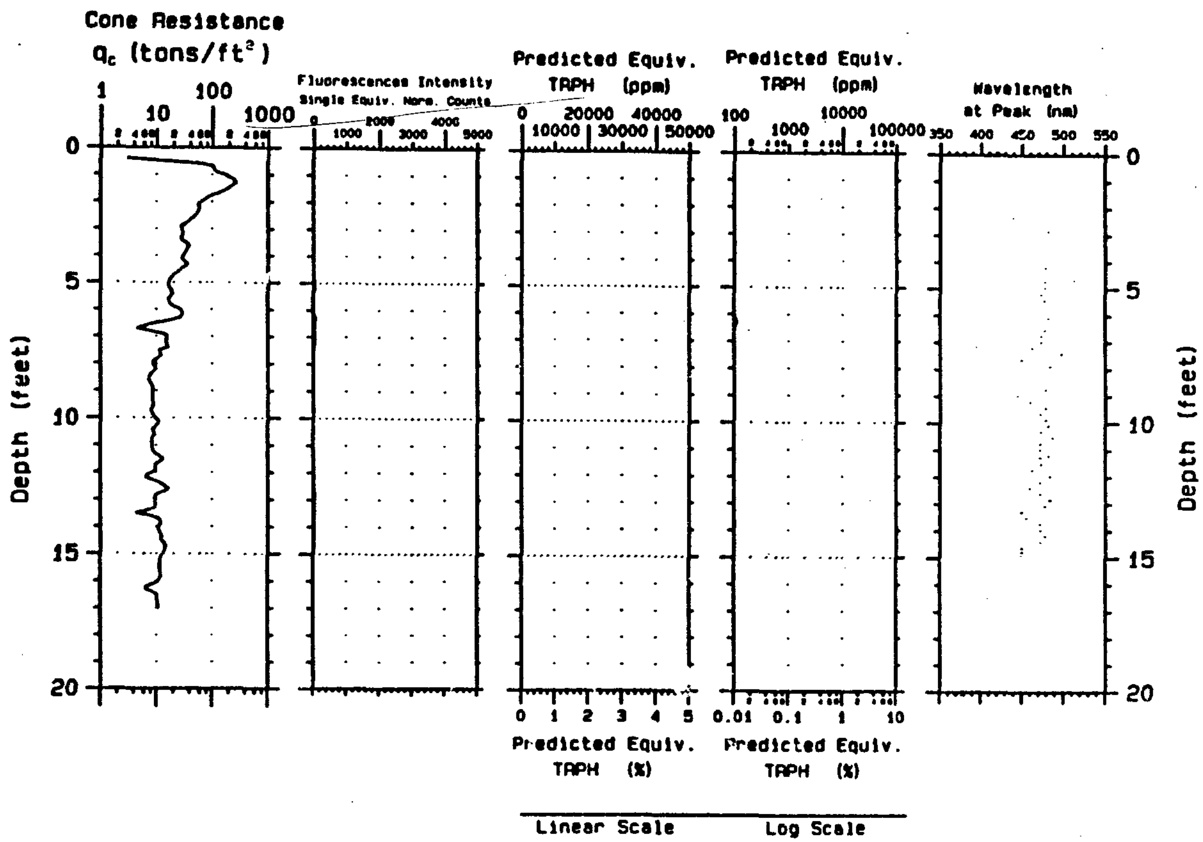
STATE COORDINATES:

EASTING (ft.) 2716569

NORTHING (ft.) 216277

1 foot = 0.3048 meter
1 ton/ft² = 0.958 bars

Figure 49. Results of probe 3 at the DRMO site.



CPT: CP-DM-04 Project: Philadelphia Naval Shipyard

STATE COORDINATES:

EASTING (ft.) NORTHING (ft.)

2716547 216237

1 foot = 0.3048 meters

1 ton/ft² = 0.958 bars

Figure 50. Results of probe 4 at the DRMO site.

Table 3. Summary of results for the DRMO site.

PROBE NAME	DEPTH INVESTIGATED (FROM GROUND SURFACE)	PRODUCT ENCOUNTERED	POSSIBLE PRODUCT
CP-DM-01	0 - 18 ft	yes; 5-7 ft	Fuel oil
CP-DM-02	0 - 18 ft	yes; 3-7 ft	Fuel oil
CP-DM-03	0 - 18 ft	yes; 4-7 ft	Fuel oil
CP-DM-04	0 - 18 ft	no	NA

49. The three dimensional representations of data for this site are shown in Figures 51 and 52. Both views are looking southwest to northeast. In Figure 51 the data for concentrations above 100 ppm are displayed. The largest amount of product encountered was from probe CP-DM-02, which was directly across from the oil water separator. Figure 52 shows the same data at a slightly different rotation and tilt. Although the data seem to be isolated around each probe, it is probably more realistically one large plume that has spread out over the course of time. The gridding algorithm was constrained to prevent any large extrapolations due to the limited number of probes in the area. Additional probes could easily outline the extent of the plume.

Crane Shop Results

50. A total of ten pushes were completed around the crane shop with the two dimensional results presented in Figures 53-62, and the three dimensional results presented in Figures 63-68. The results of each probe are discussed following and summarized in Table 4. Probe one encountered product at a depth of 4 ft and between depths of 7-10 ft with a very small amount detected at 11.5 ft. Push two detected product between 6.5-9 ft and between 11-13 ft. Push three resulted in a broken probe at a depth of 4 ft and therefore yielded no meaningful results. Push four detected nothing above the minimum resolution threshold. Push five detected a very small amount of product at 7.5 ft and between depths of 10.5 to 12.5 ft. Push six, seven, eight, and nine either did not detect anything above the minimum resolution threshold, or

PNSY
DRMO SITE

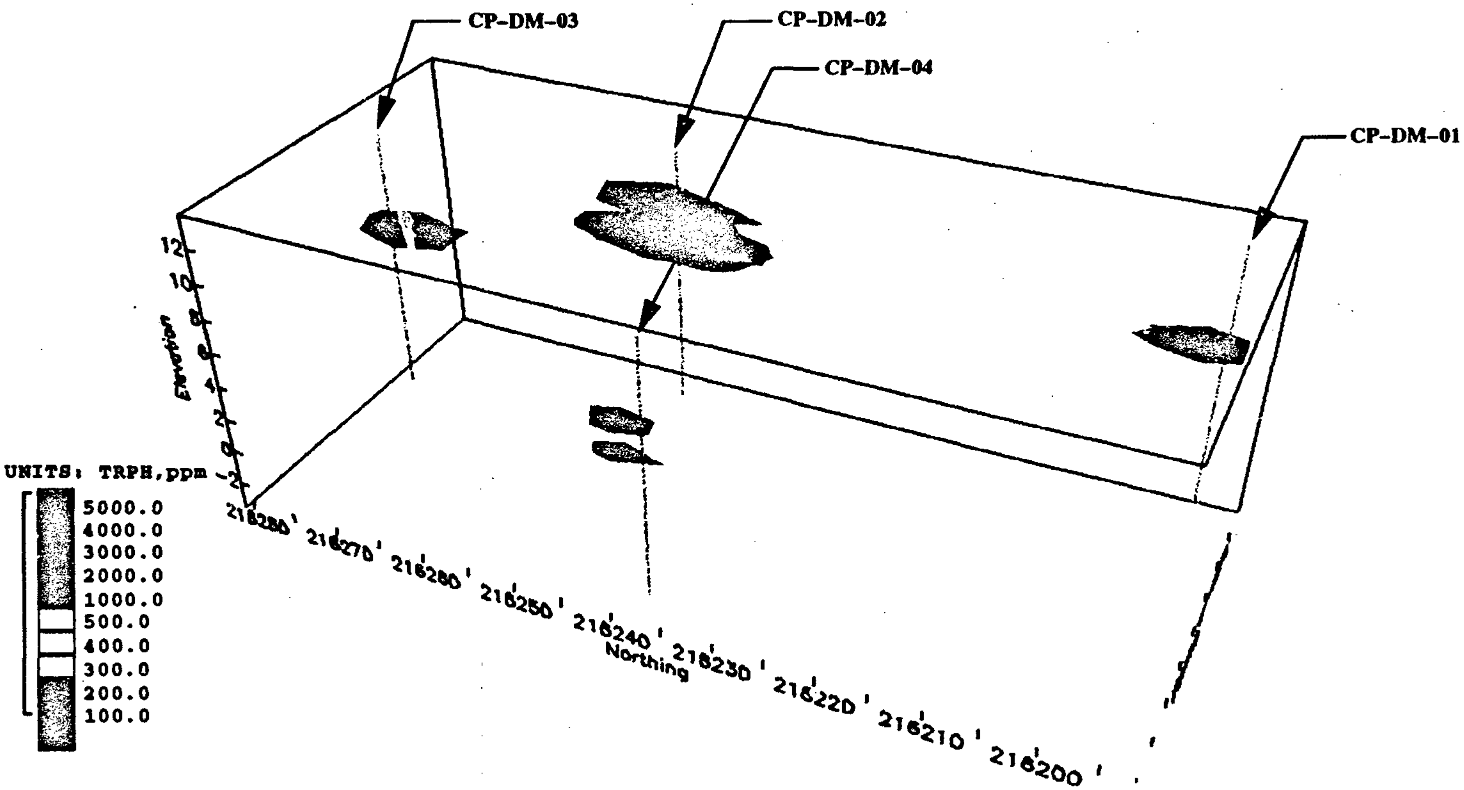


Figure 51. Volumetric representation of DRMO results showing TRPH above 100 ppm.

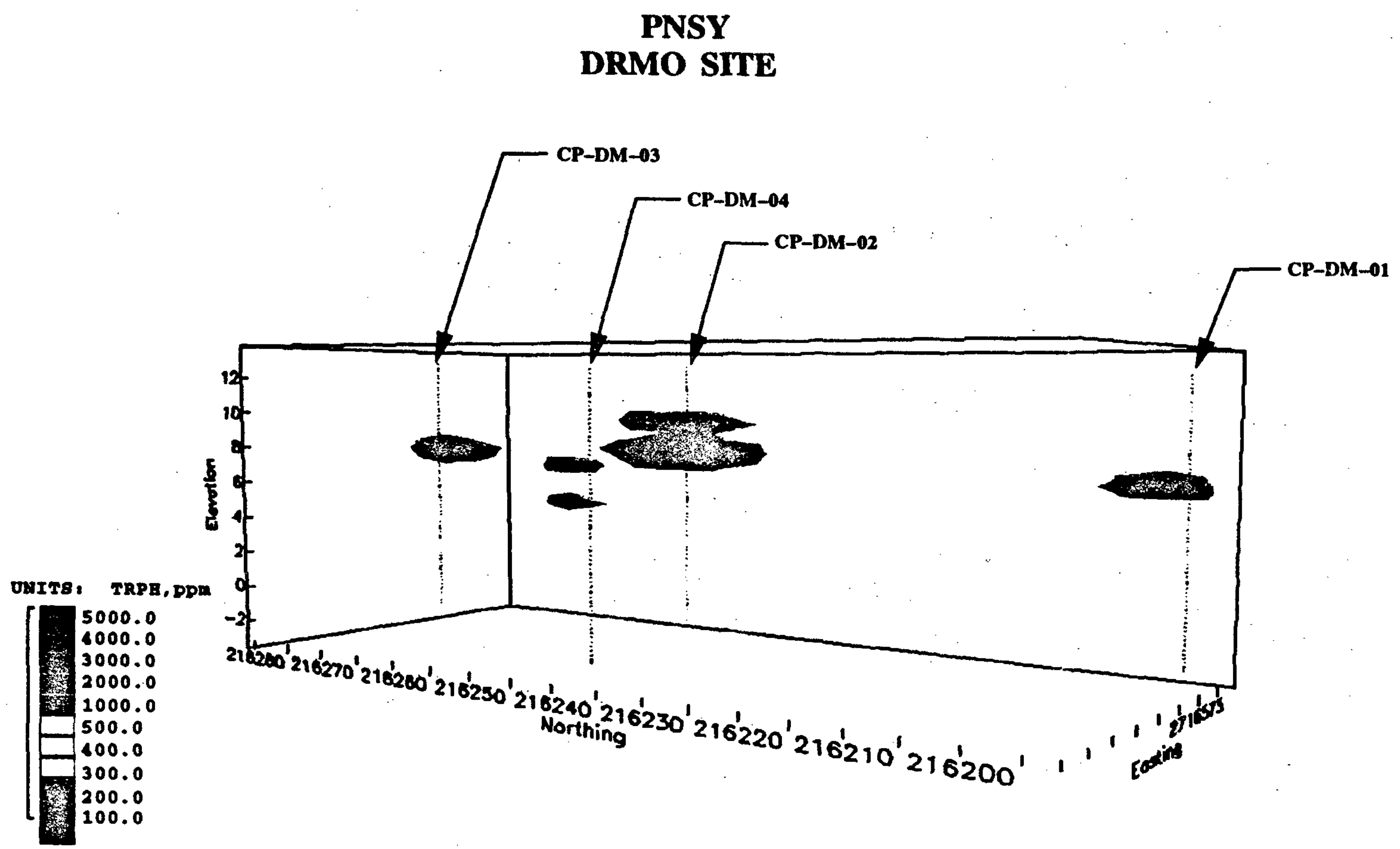
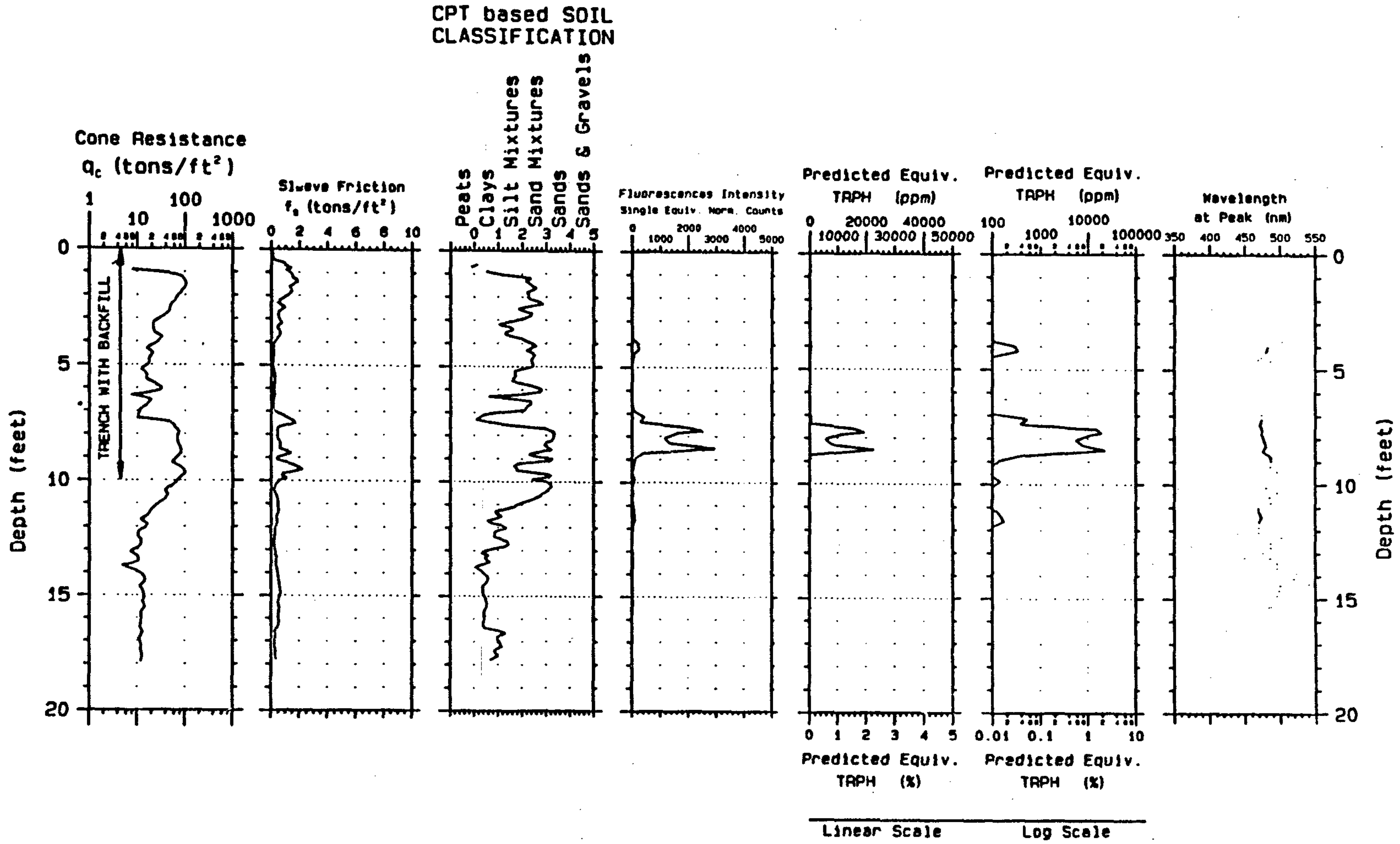


Figure 52. Volumetric representation of DRMO results showing TRPH above 100 ppm, side view looking west to east.



CPT: CP-CS-01 Project: Philadelphia Naval Shipyard

STATE COORDINATES:

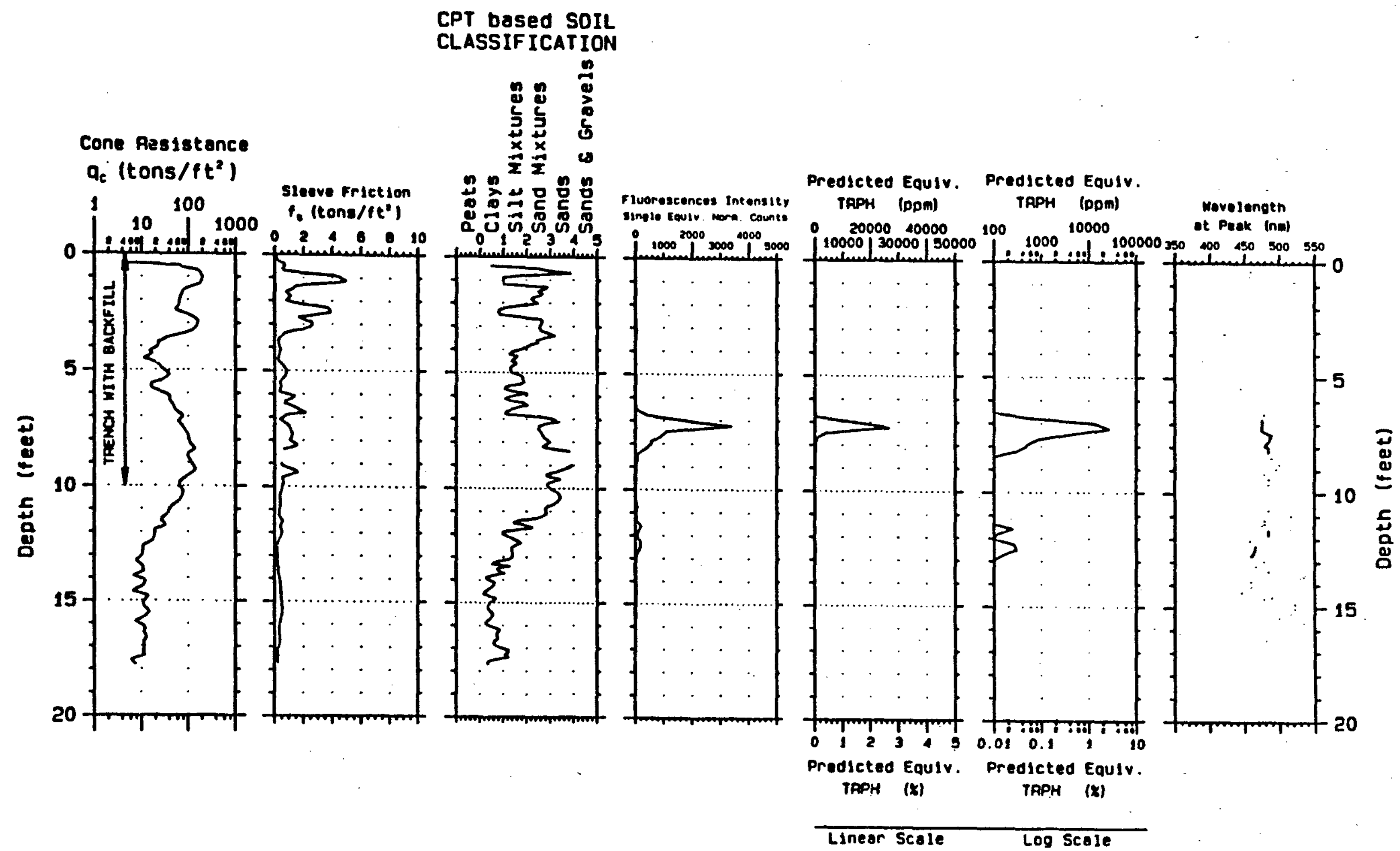
EASTING (ft.) 2721946

NORTHING (ft.) 216117

1 foot = 0.3048 meters

1 ton/ft² = 0.958 bars

Figure 53. Results of probe 1 at the Crane Shop site.

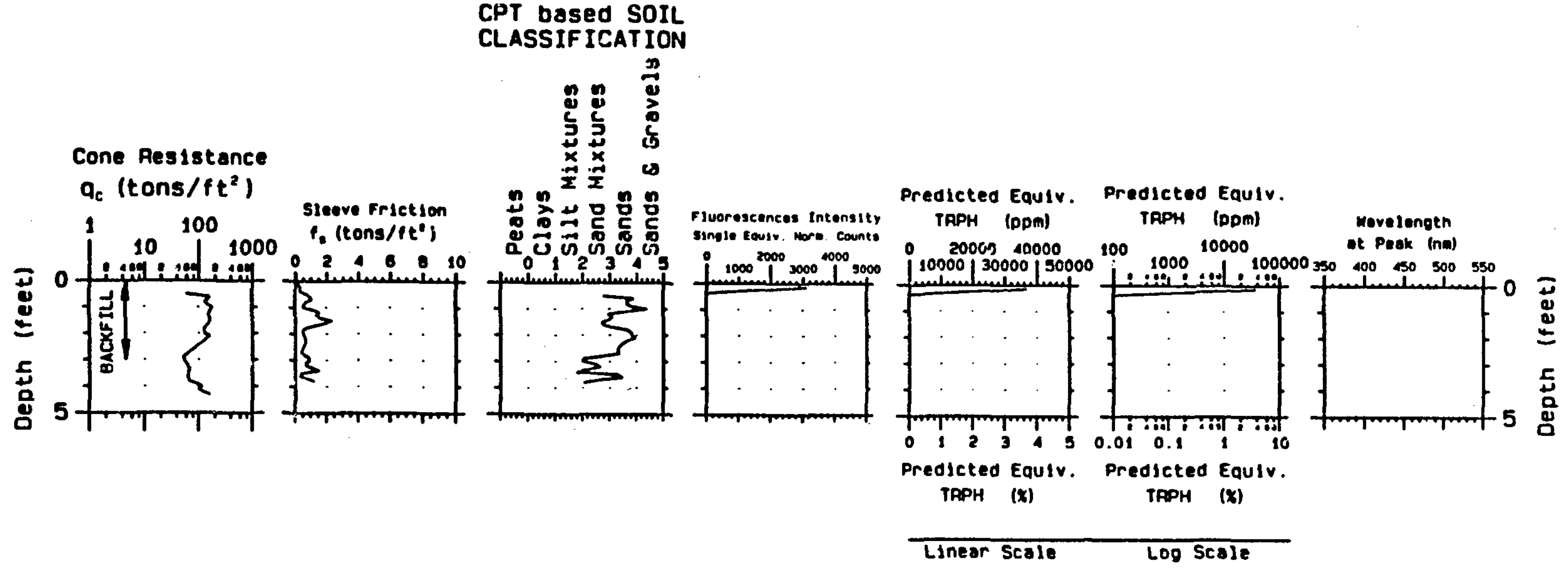


CPT: CP-CS-02
STATE COORDINATES:
EASTING (ft.) 2721911
NORTHING (ft.) 216113

Project: Philadelphia Naval Shipyard

1 foot = 0.3048 meters
1 ton/ft² = 0.958 bars

Figure 54. Results of probe 2 at the Crane Shop site.



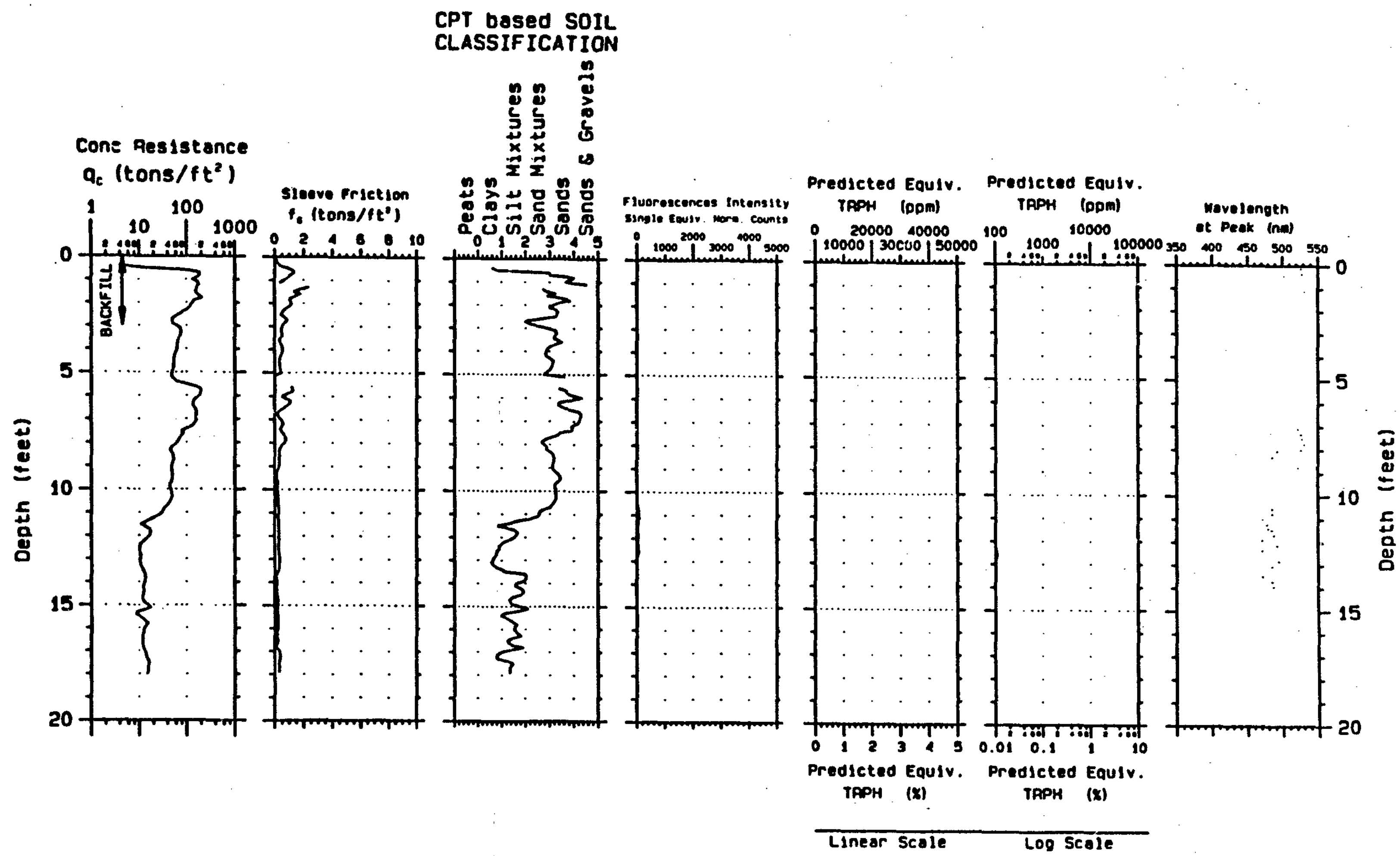
CPT: CP-CS-03 Project: Philadelphia Naval Shipyard

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)
2721721	216323

1 foot = 0.3048 meters
1 ton/ft^2 = 0.958 bars

Figure 55. Results of probe 3 at the Crane Shop site.

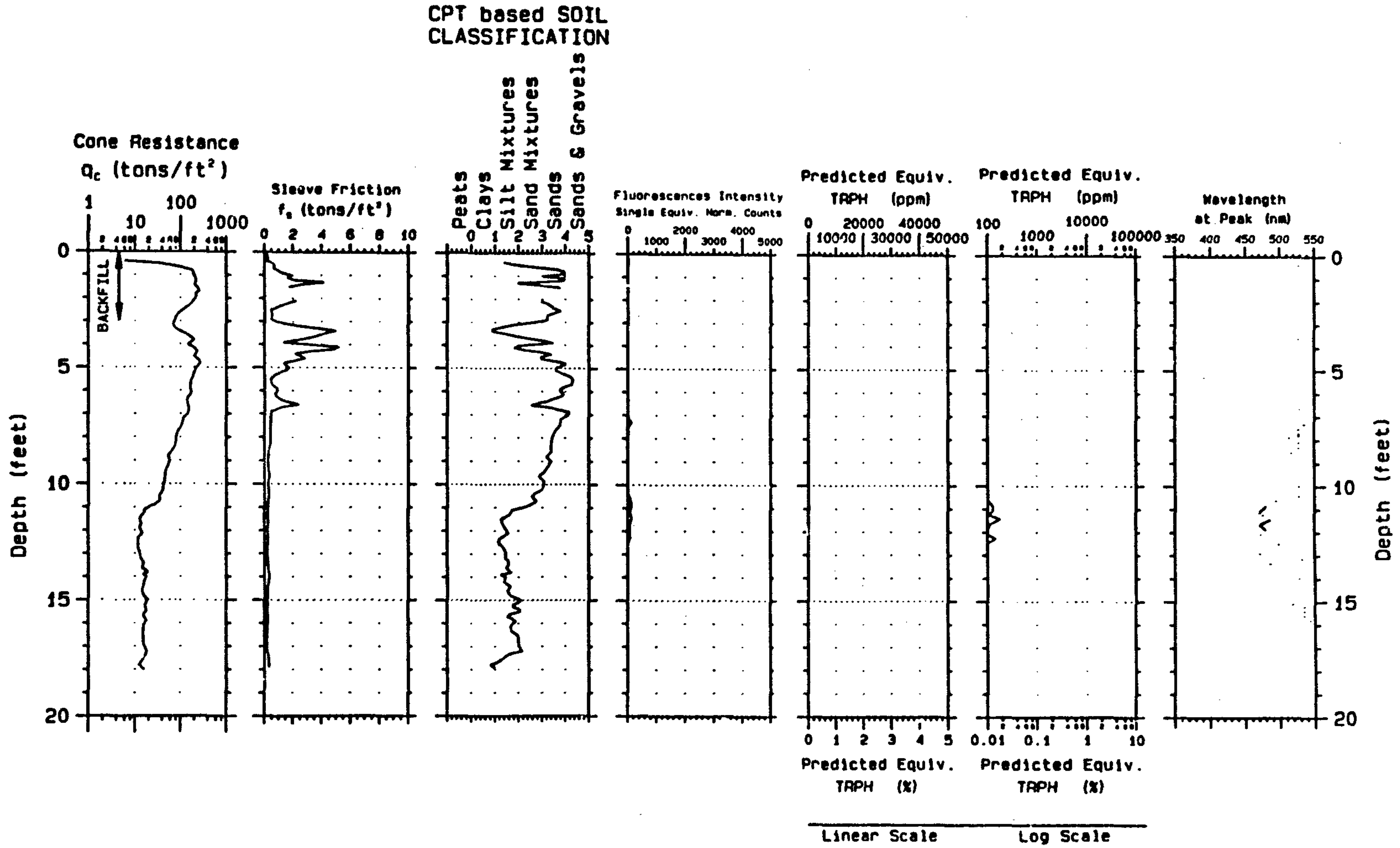


CPT: CP-CS-04 Project: Philadelphia Naval Shipyard

STATE COORDINATES:
EASTING (ft.) 2721695 NORTHING (ft.) 216317

1 foot = 0.3048 meters
1 ton/ft² = 0.958 bars

Figure 56. Results of probe 4 at the Crane Shop site.



CPT: CP-CS-05

Project: Philadelphia Naval Shipyard

STATE COORDINATES:

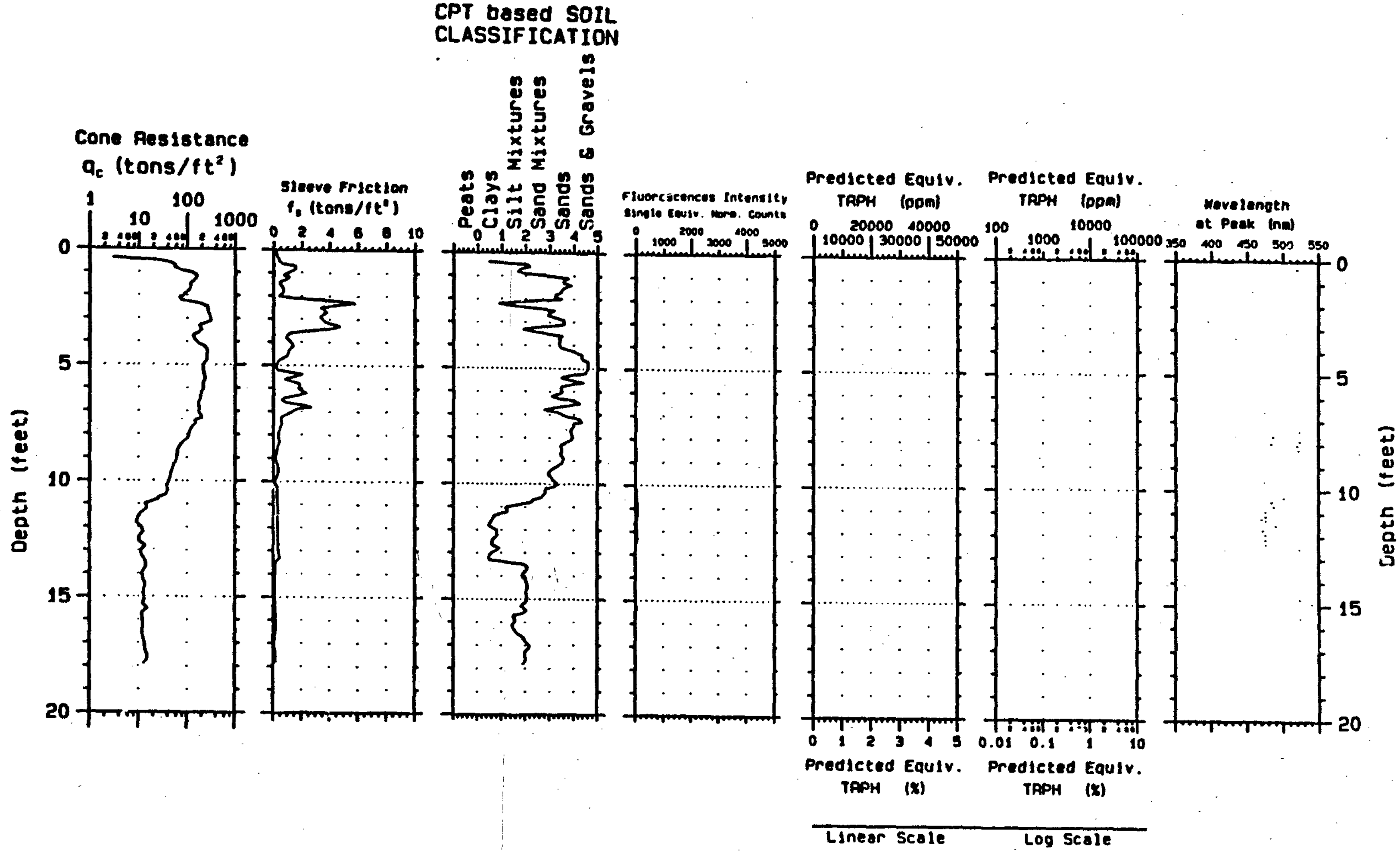
EASTING (ft.) 2721667

NORTHING (ft.) 216311

1 foot = 0.3048 meters

1 ton/ft² = 0.958 bars

Figure 57. Results of probe 5 at the Crane Shop site.



CPT: CP-CS-06

STATE COORDINATES:

EASTING (ft.) 2721269

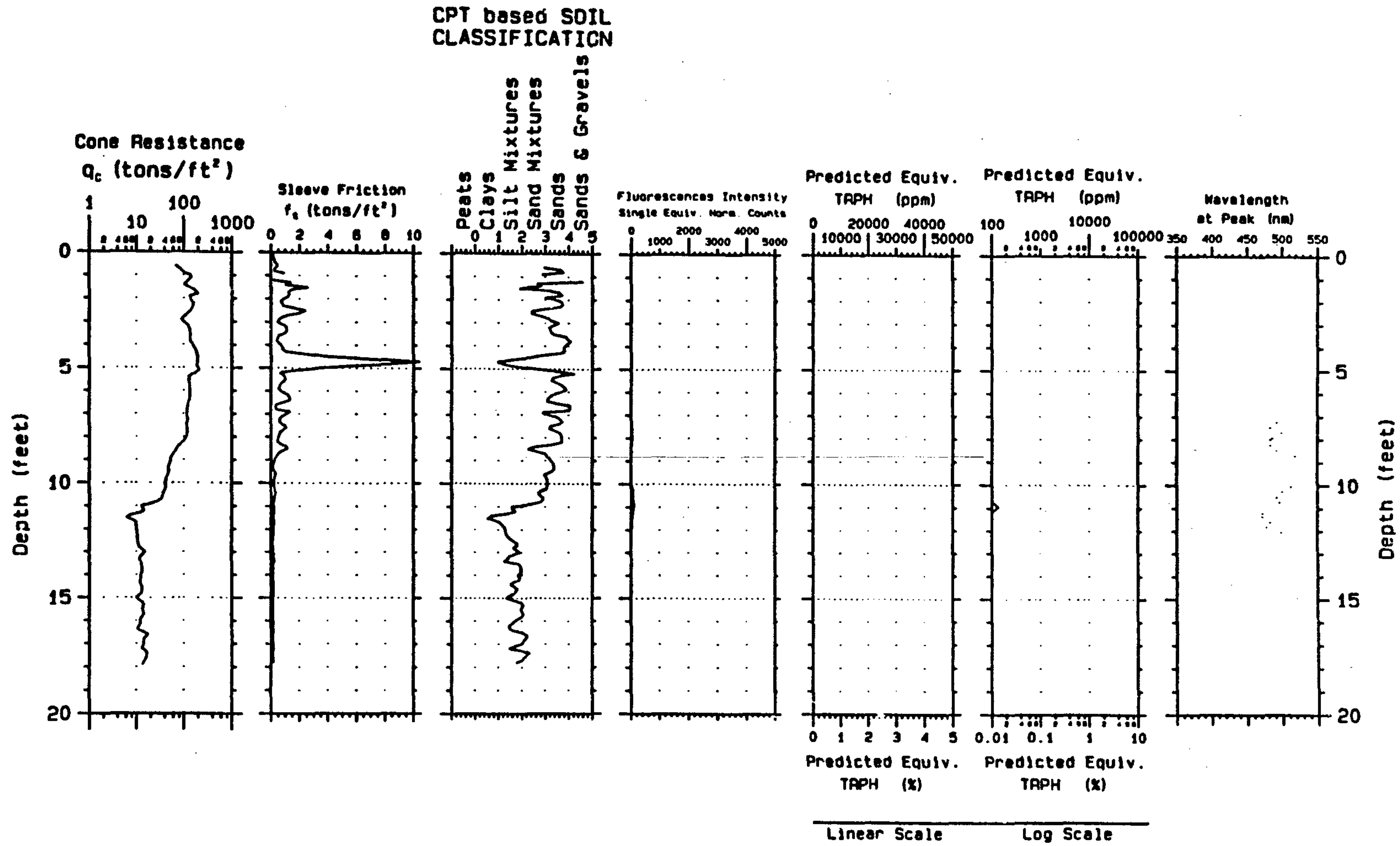
NORTHING (ft.) 216306

Project: Philadelphia Naval Shipyard

1 foot = 0.3048 meters

1 ton/ft^2 = 0.958 bars

Figure 58. Results of probe 6 at the Crane Shop site.



CPT: CP-CS-07

Project: Philadelphia Naval Shipyard

STATE COORDINATES:

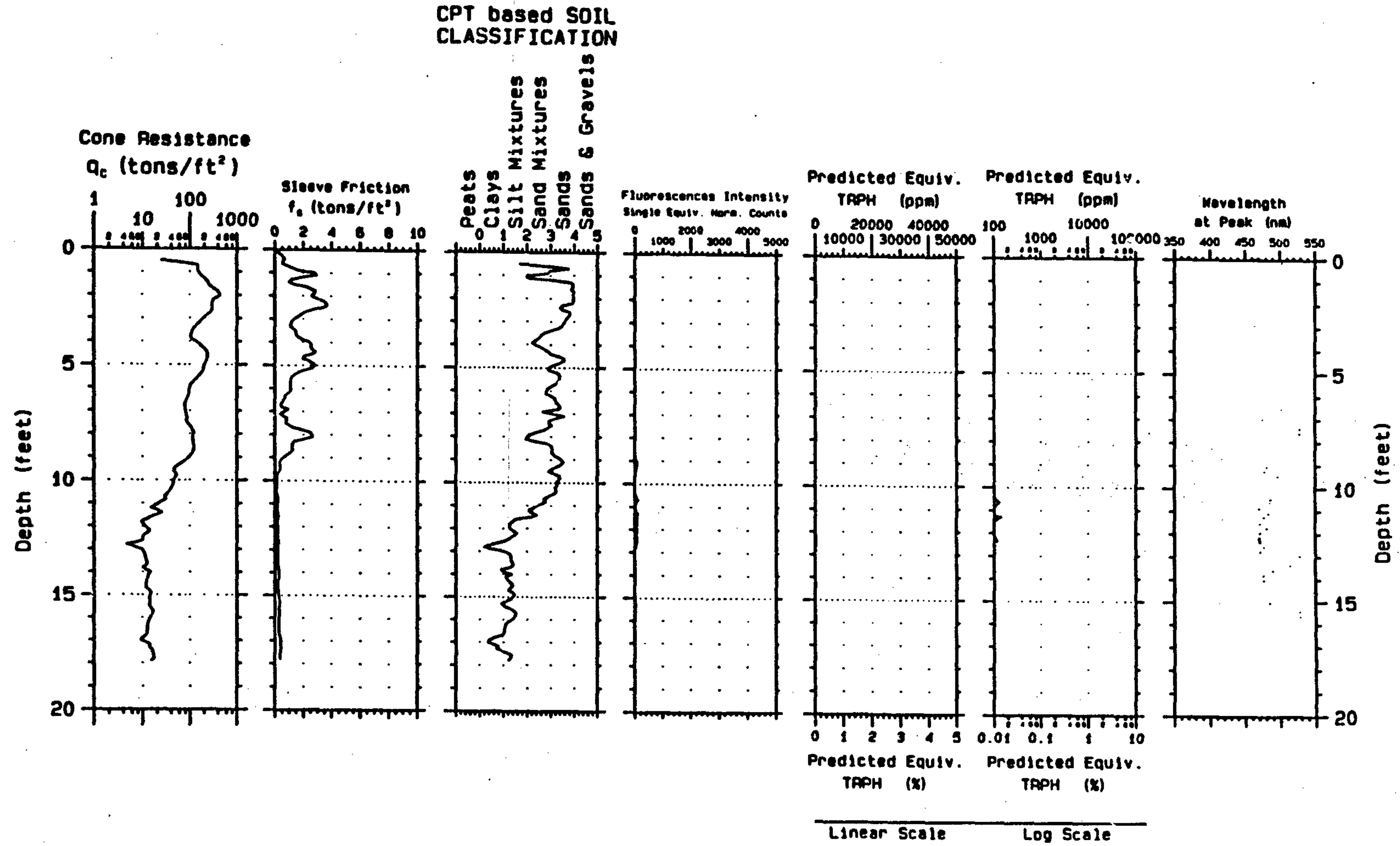
EASTING (ft.) 2721564

NORTHING (ft.) 216288

1 foot = 0.3048 meters

1 ton/ft^2 = 0.958 bars

Figure 59. Results of probe 7 at the Crane Shop site.



CPT: CP-CS-08

Project: Philadelphia Naval Shipyard

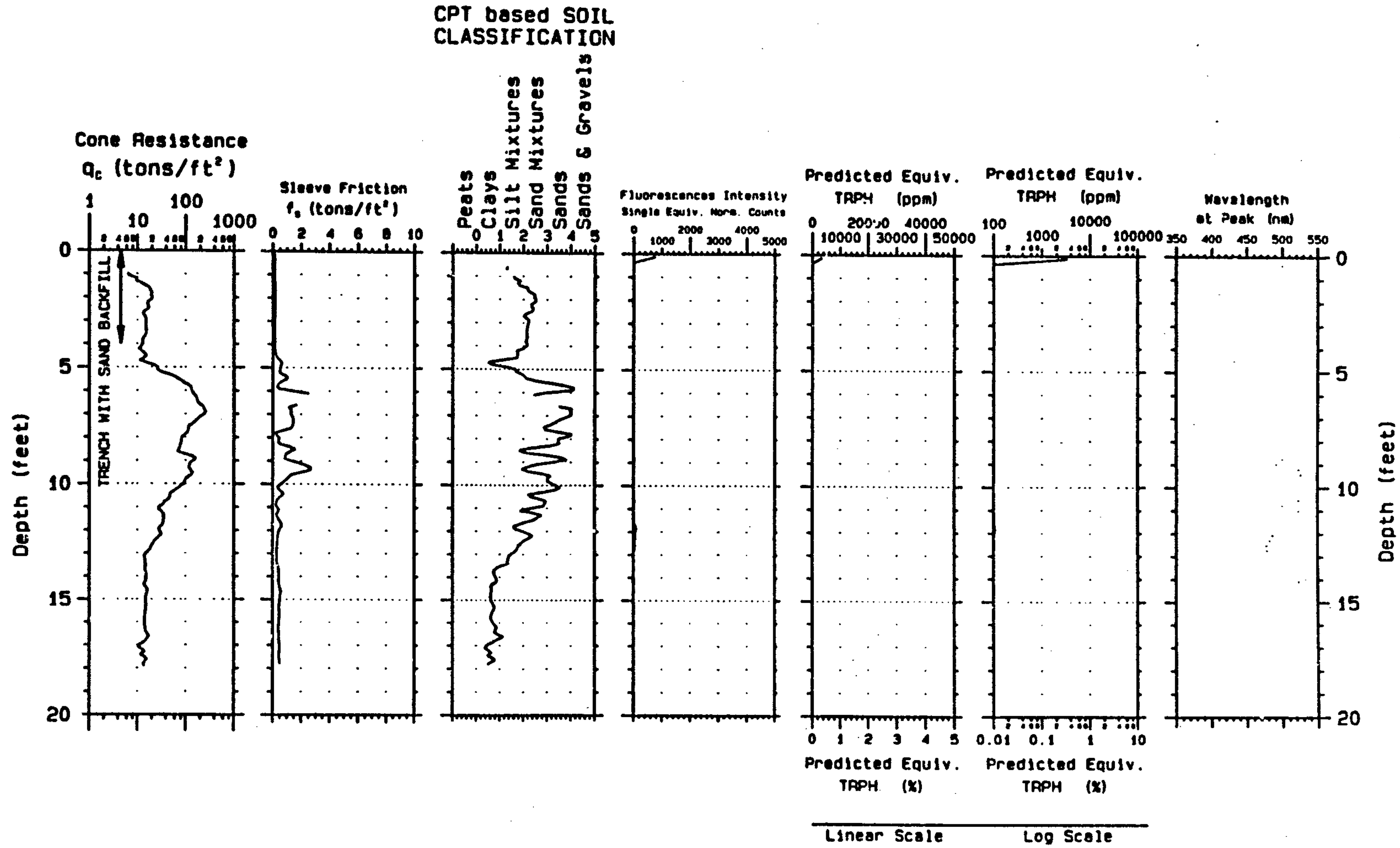
STATE COORDINATES:

EASTING (ft.)
2721791

NORTHING (ft.)
216332

1 foot = 0.3048 meters
1 ton/ft^2 = 0.958 bars

Figure 60. Results of probe 8 at the Crane Shop site.



CPT: CP-CS-09 Project: Philadelphia Naval Shipyard

STATE COORDINATES:

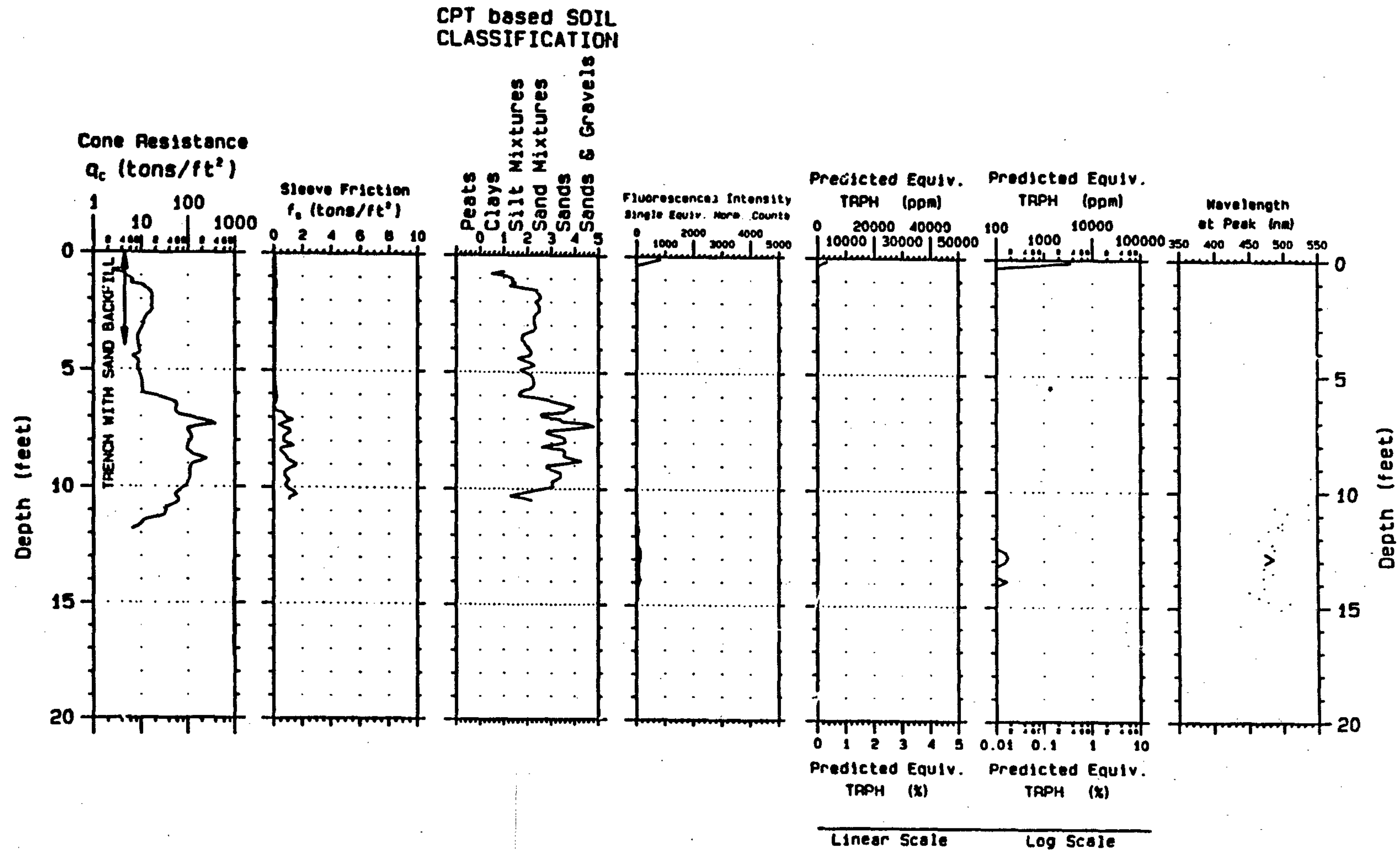
EASTING (ft.) 2721859

NORTHING (ft.) 216118

1 foot = 0.3048 meters

1 ton/ft² = 0.958 bars

Figure 61. Results of probe 9 at the Crane Shop site.



CPT: CP-CS-10

Project: Philadelphia Naval Shipyard

STATE COORDINATES:

EASTING (ft.) 2721898

NORTHING (ft.) 216125

1 foot = 0.3048 meters
1 ton/ft² = 0.958 bars

Figure 62. Results of probe 10 at the Crane Shop site.

detected very small trace amounts which are probably not significant. Push ten did detect a small amount of product between 13-14 ft.

Table 4. Summary of results for the Crane Shop site.

PROBE NAME	DEPTH INVESTIGATED (FROM GROUND SURFACE)	PRODUCT ENCOUNTERED	POSSIBLE PRODUCT
CP-CS-01	0 - 18 ft	yes; 4, 7-10, 11.5 ft	Fuel oil
CP-CS-02	0 - 18 ft	yes; 6.5-9, 11-13 ft	Fuel oil
CP-CS-03	0 - 4 ft	no	NA
CP-CS-04	0 - 18 ft	no	NA
CP-CS-05	0 - 18 ft	yes; 7.5, 10.5-12.5 ft	Fuel oil
CP-CS-06	0 - 18 ft	no	NA
CP-CS-07	0 - 18 ft	no	NA
CP-CS-08	0 - 18 ft	no	NA
CP-CS-09	0 - 18 ft	no	NA
CP-CS-10	0 - 18 ft	yes; 13-14 ft	Fuel oil

51. The three dimensional representations of the data from this area are presented in Figures 63-66. Figures 63 and 64 show the data collected along the side of building 753, while Figures 65 and 66 show the data collected northwest of building 753 parallel to the base boundary. Figure 63 is a view of the concentrations above 100 ppm, looking approximately southeast to northwest. The majority of the data are located around the area where a tank had been removed. It appears as though some contamination was left near the bottom of the excavation. Figure 64, looking south to north, shows the vertical and lateral extent of the contaminant. Figures 65 and 66 show very small patches of contaminant at depth.

NAVSSES Results

52. The results of pushes completed in the NAVSSES area are shown in two

PNSY
CRANE SHOP

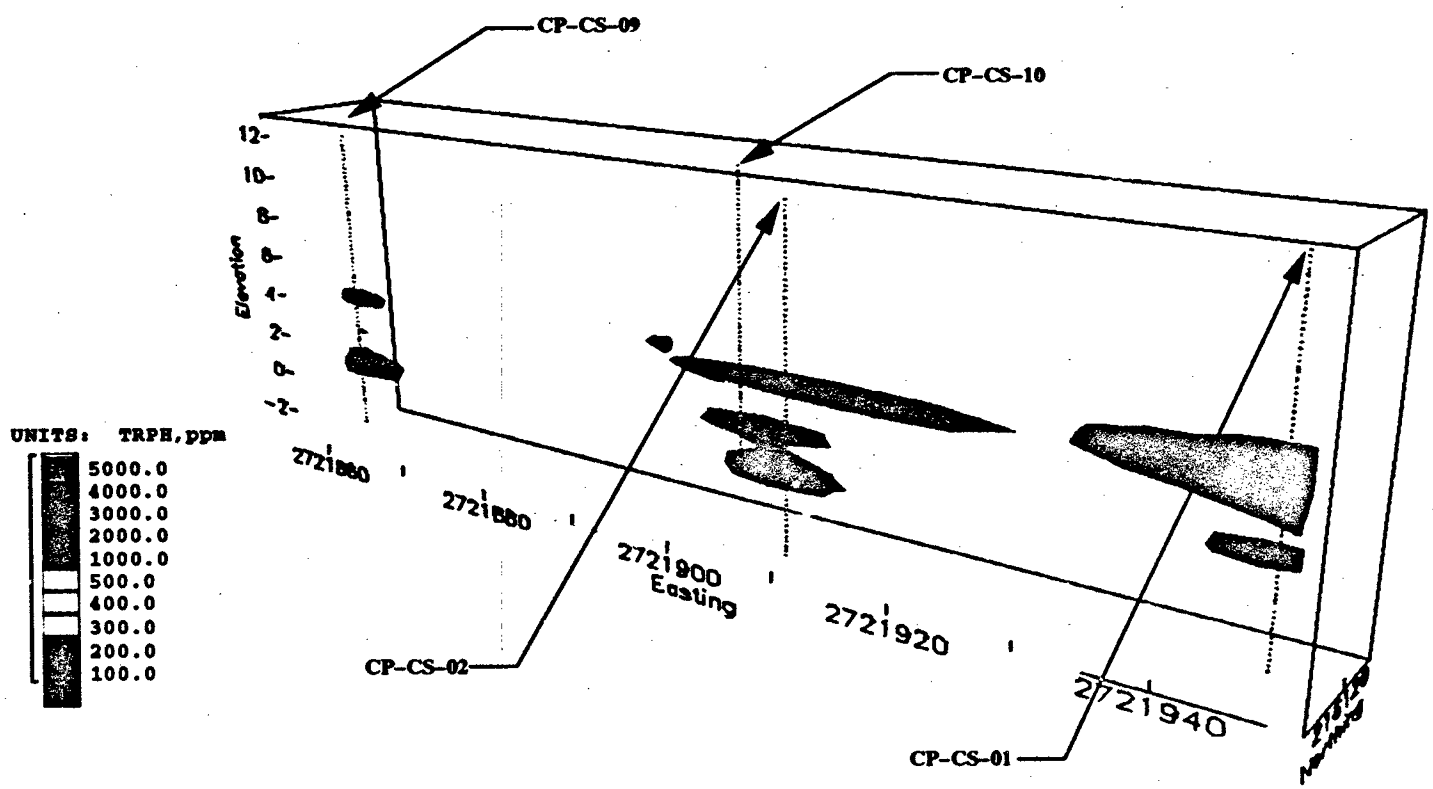


Figure 63. Volumetric representation of Crane Shop results near building 763 showing TRPH above 100 ppm.

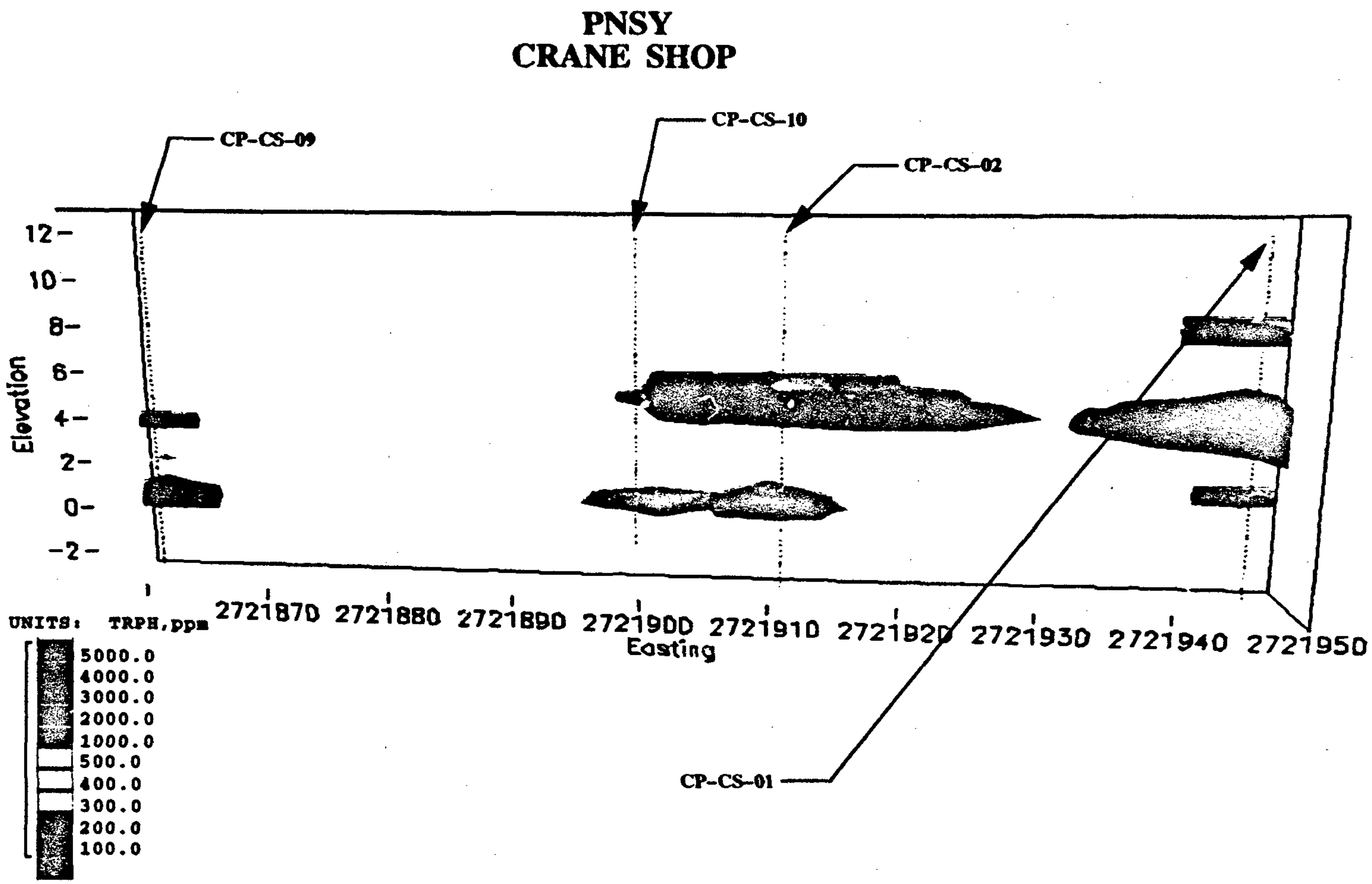


Figure 64. Volumetric representation of Crane Shop results near building 763 showing TRPH above 100 ppm, side view looking south to north.

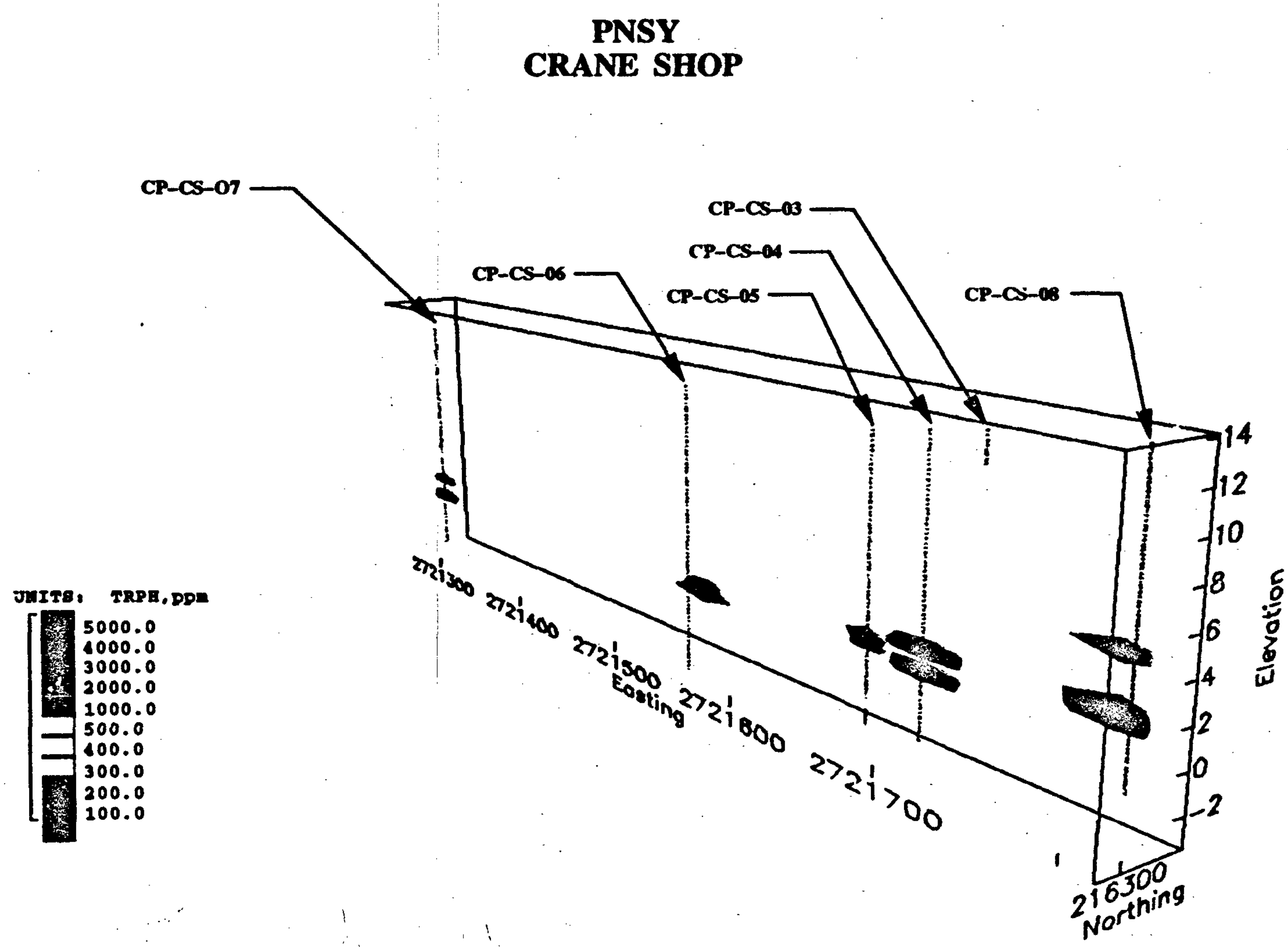


Figure 65. Volumetric representation of Crane Shop results near boundary showing TRPH above 100 ppm.

PNSY
CRANE SHOP

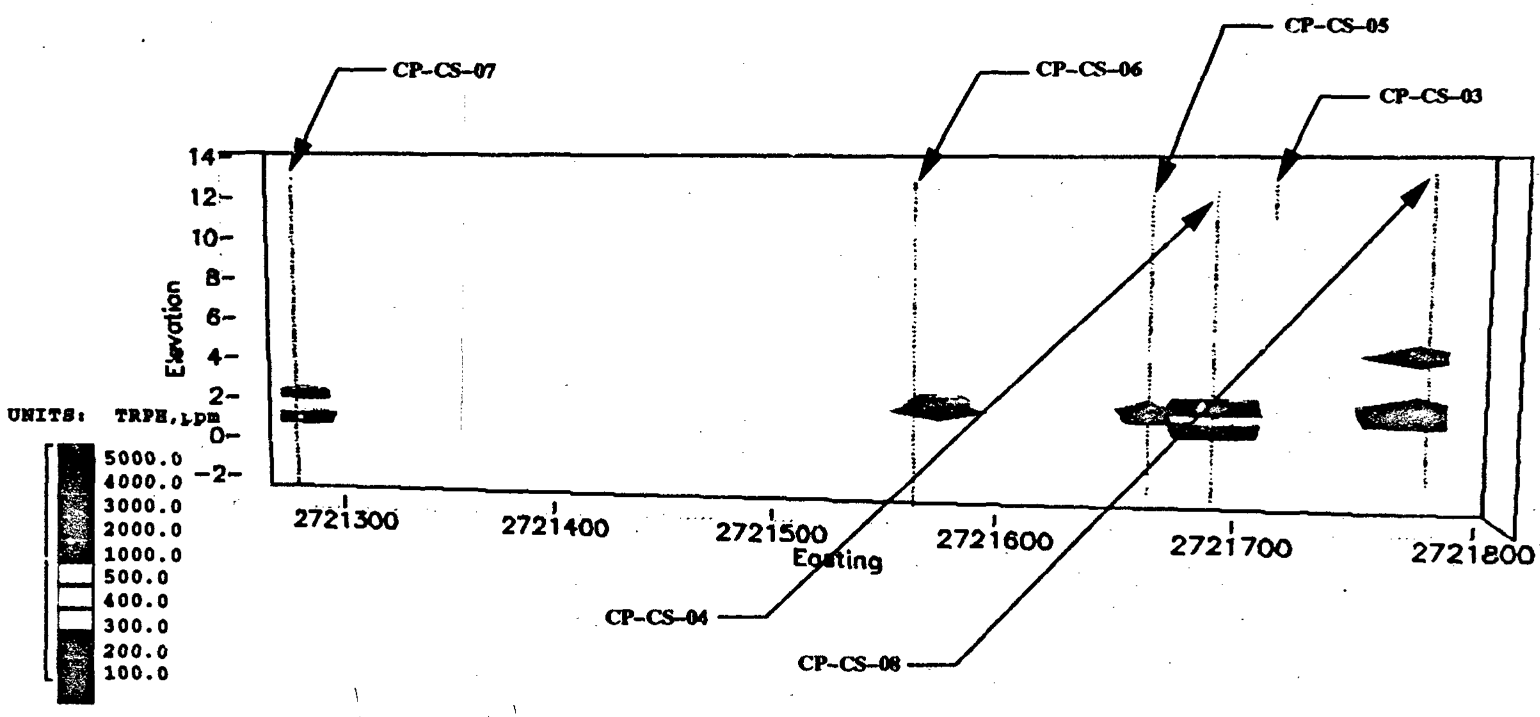


Figure 66. Volumetric representation of Crane Shop results near boundary showing TRPH above 100 ppm, side view looking south to north.

dimensional form in Figures 67-69 and in three dimensional form in Figures 70 and 71. The results of each push are discussed following and summarized in Table 5. There were a total of three pushes performed at this site. Push one detected product from the surface down to a depth of 5 ft. Push two detected product from the surface to a depth of 5 ft very similar to push one. The third push detected product between depths of 2 and 4 ft.

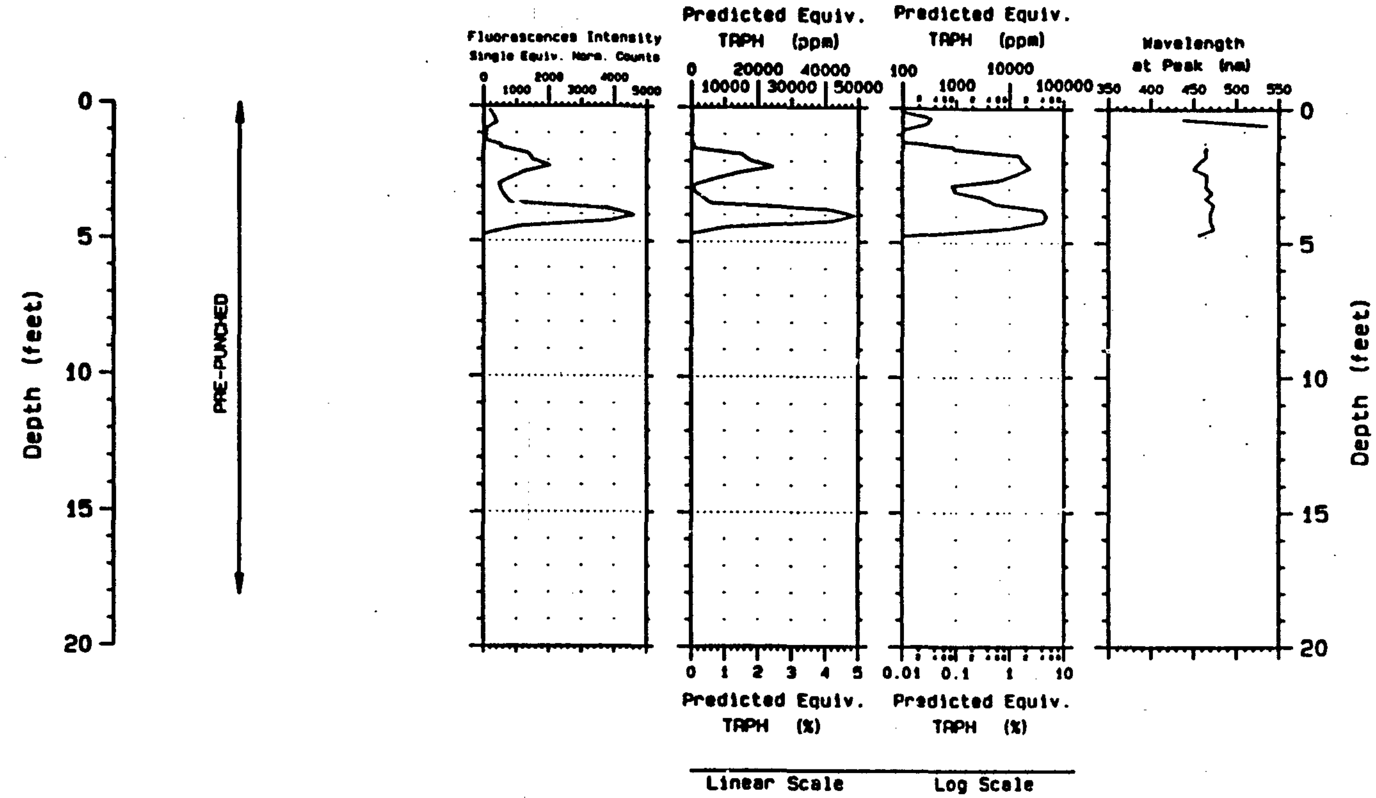
Table 5. Summary of results for the NAVSSES site.

PROBE NAME	DEPTH INVESTIGATED (FROM GROUND SURFACE)	PRODUCT ENCOUNTERED	POSSIBLE PRODUCT
CP-NS-01	0 - 18 ft	yes; 0-5 ft	Fuel oil
CP-NS-02	0 - 18 ft	yes; 0-5 ft	Fuel oil
CP-NS-03	0 - 18 ft	yes; 2-4 ft	Fuel oil

53. The three dimensional representations of the data for this site are shown in Figures 70 and 71. Figure 70, looking southwest to northeast, shows the data with concentrations above 100 ppm. There is a large plume extending between probes one and two that could even extend as far as probe three if additional probes had been placed in the area. In addition, the plume undoubtedly extends laterally much farther than is shown in the Figures (the plume being constrained to data collected). Figure 71 shows the vertical extent of the plume.

Runway Results

54. The results of the probes in this area are shown in two dimensional form in Figures 72-76 and in three dimensional form in Figure 77. There were a total of five probes completed in this area, which are summarized in Table 6. All of the probes in this area were pre-punched before probing. Push one did not indicate any counts above the minimum threshold of the system. Push two did have a very small detection at a depth of 2.5 ft which can probably be considered insignificant. Pushes three and four show high counts near the surface which are attributable to the laser firing in the open hole (trench).



CPT: CP-NS-01 Project: Philadelphia Naval Shipyard

STATE COORDINATES:

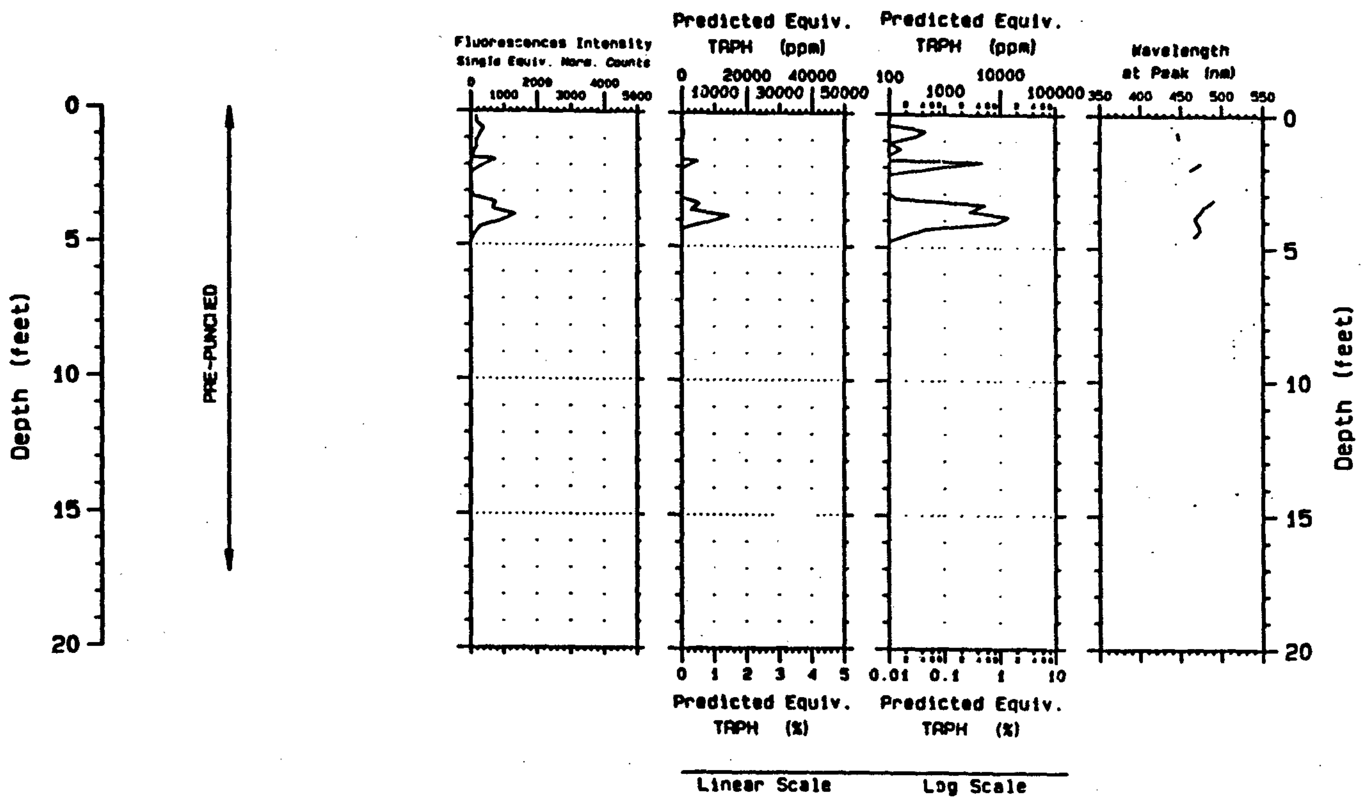
EASTING (ft.) 2721427

NORTHING (ft.) 214340

1 foot = 0.3048 meters

1 ton/ft^2 = 0.958 bars

Figure 67. Results of probe 1 at the NAVSSES site.



CPT: CP-NS-02 Project: Philadelphia Naval Shipyard

STATE COORDINATES:

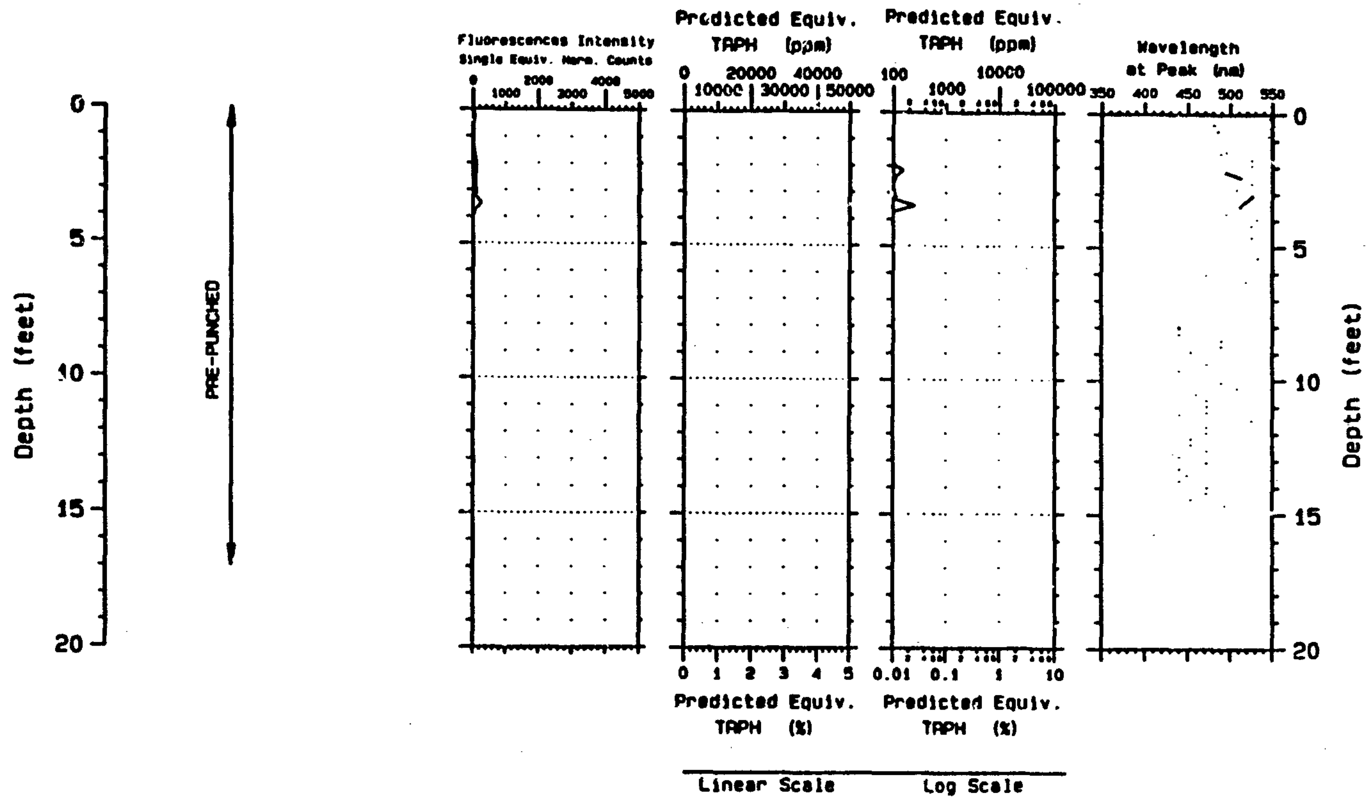
EASTING (ft.) 2721424

NORTHING (ft.) 214373

1 foot = 0.3048 meters

1 ton/ft^2 = 0.958 bars

Figure 68. Results of probe 2 at the NAVSSES site.



CPT: CP-NS-03 Project: Philadelphia Naval Shipyard

STATE COORDINATES:

EASTING (ft.) NORTHING (ft.)

2721417 214441

1 foot = 0.3048 meters

1 ton/ft^2 = 0.958 bars

Figure 69. Results of probe 3 at the NAVSSES site.

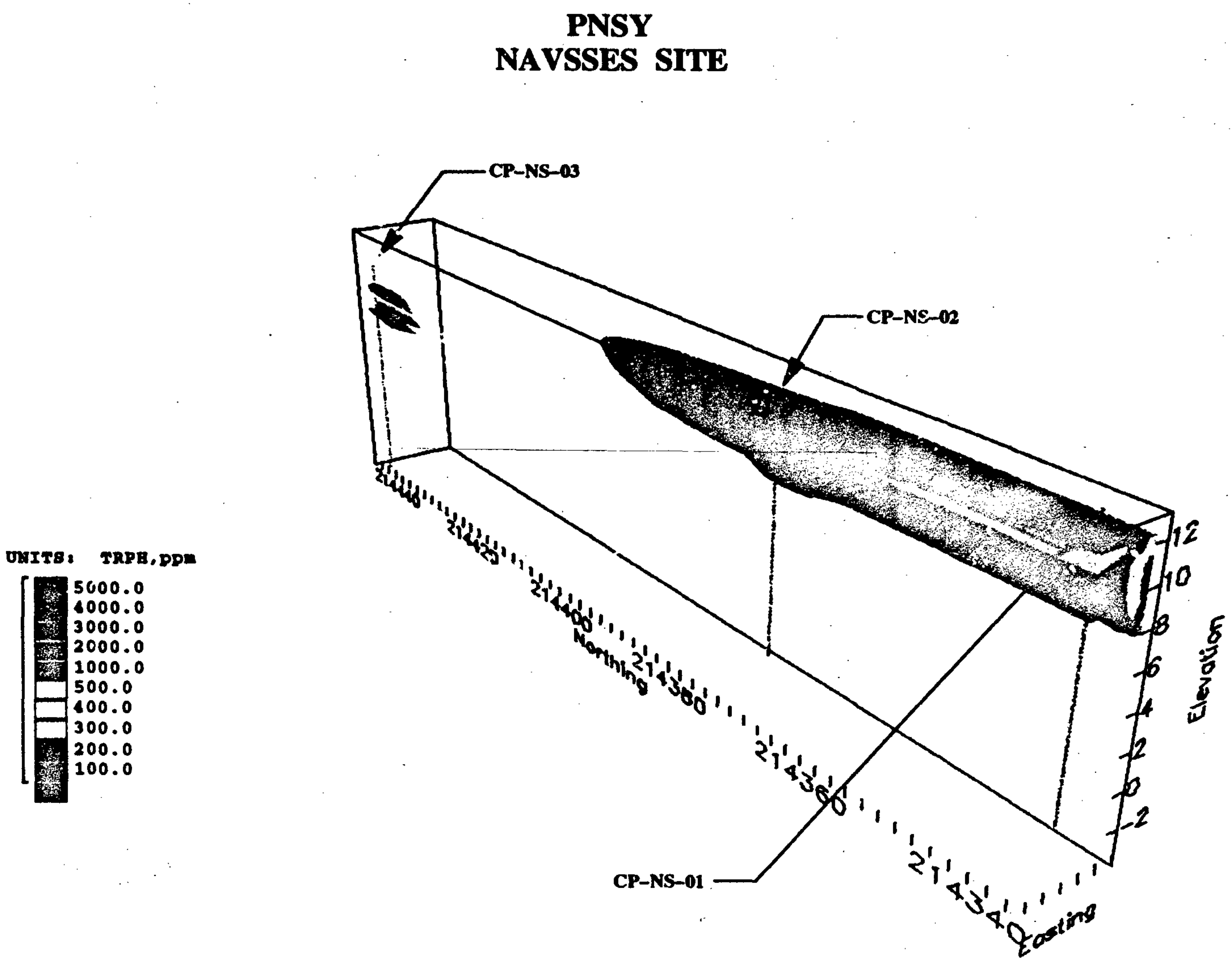


Figure 70. Volumetric representation of NAVSSES results showing TRPH above 100 ppm.

PNSY
NAVSSES SITE

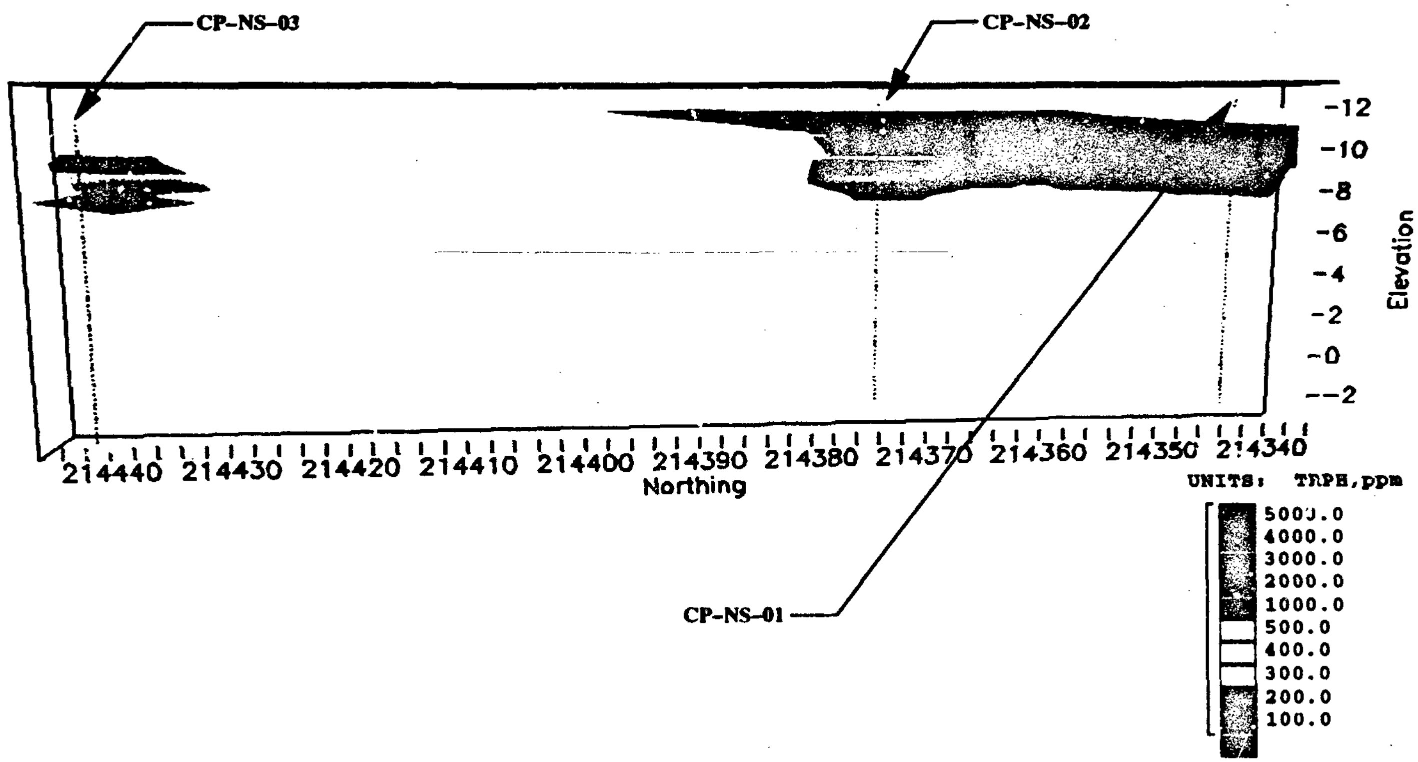
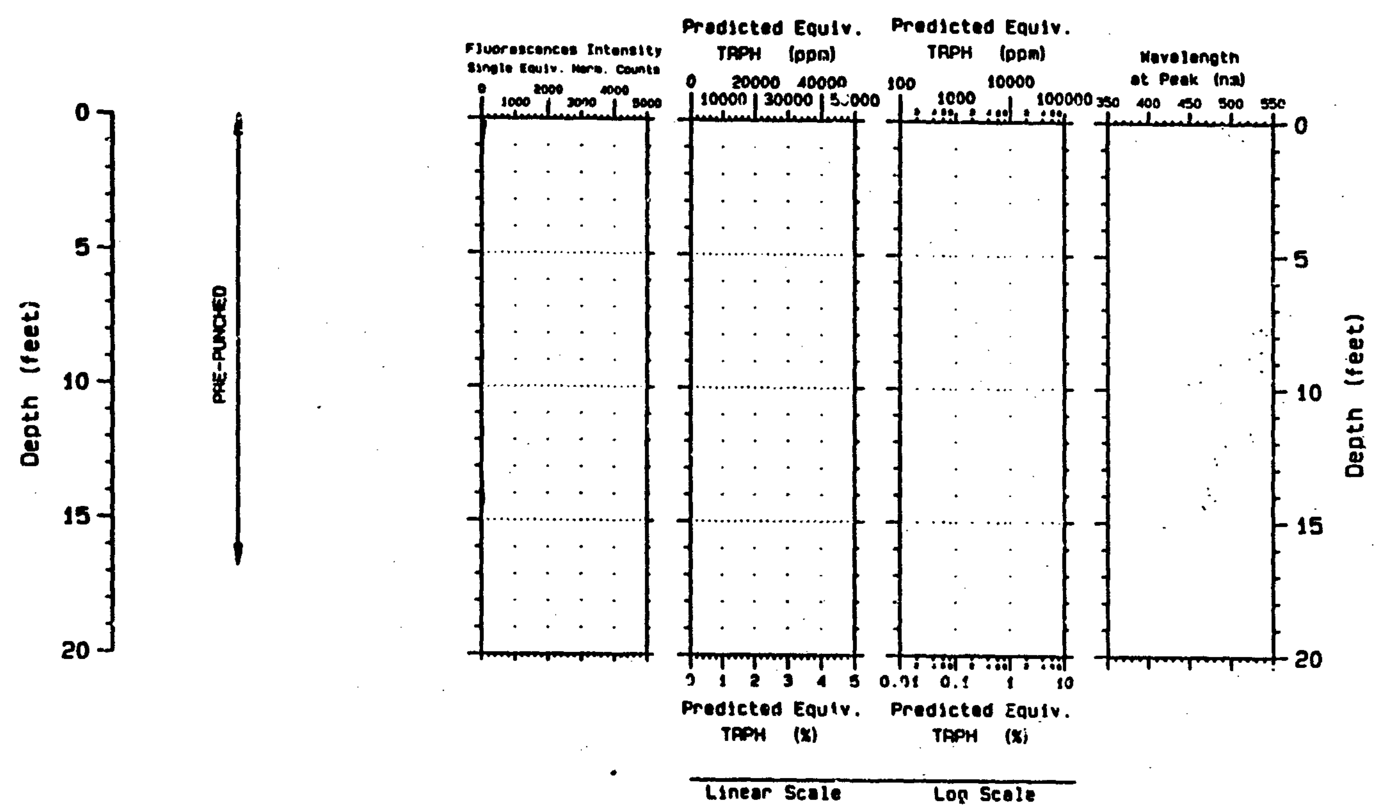


Figure 71. Volumetric representation of NAVSSES results showing TRPH above 100 ppm, side view looking west to east.



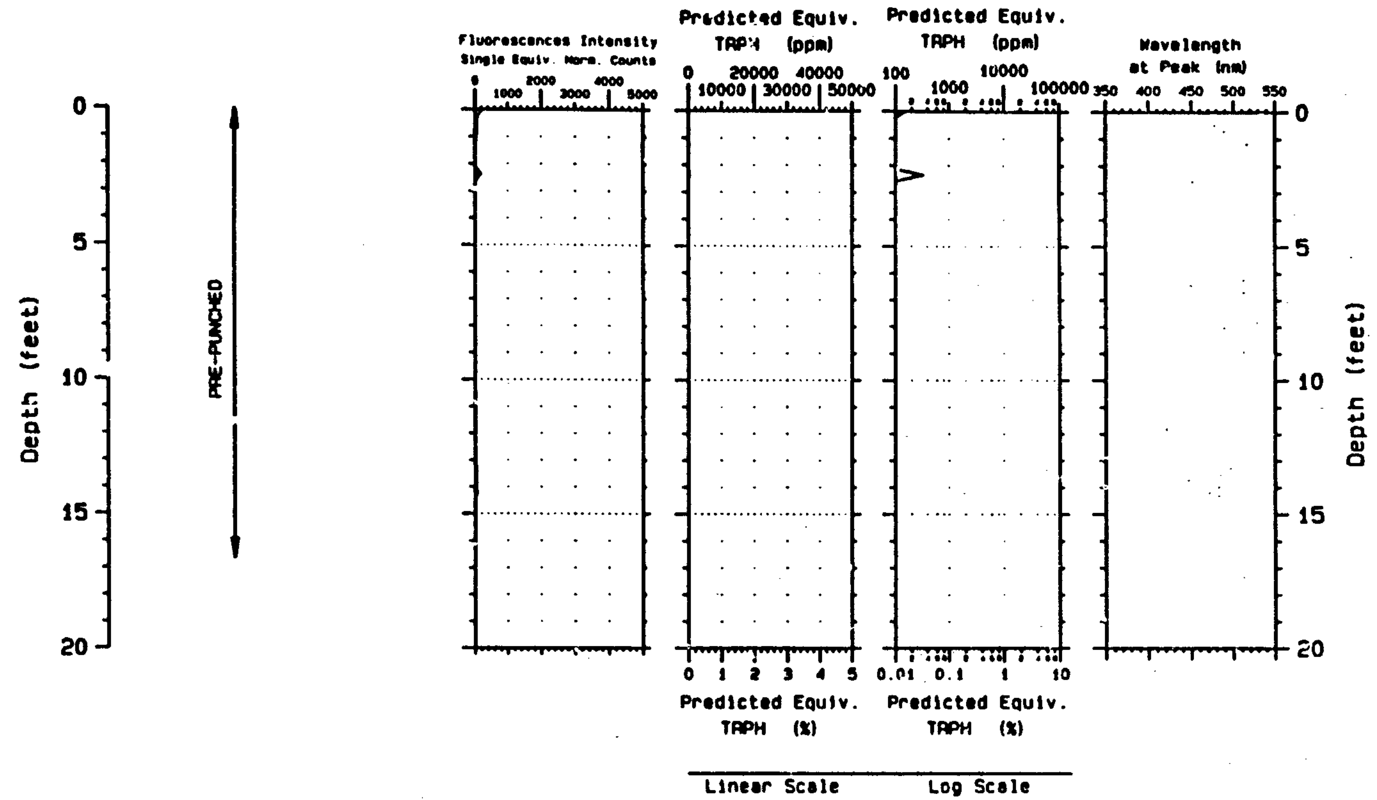
CPT: CP-RW-01 Project: Philadelphia Naval Shipyard

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)
2728135	212856

1 foot = 0.3048 meters
1 ton/ft^2 = 0.958 bars

Figure 72. Results of probe 1 at the Runway site.



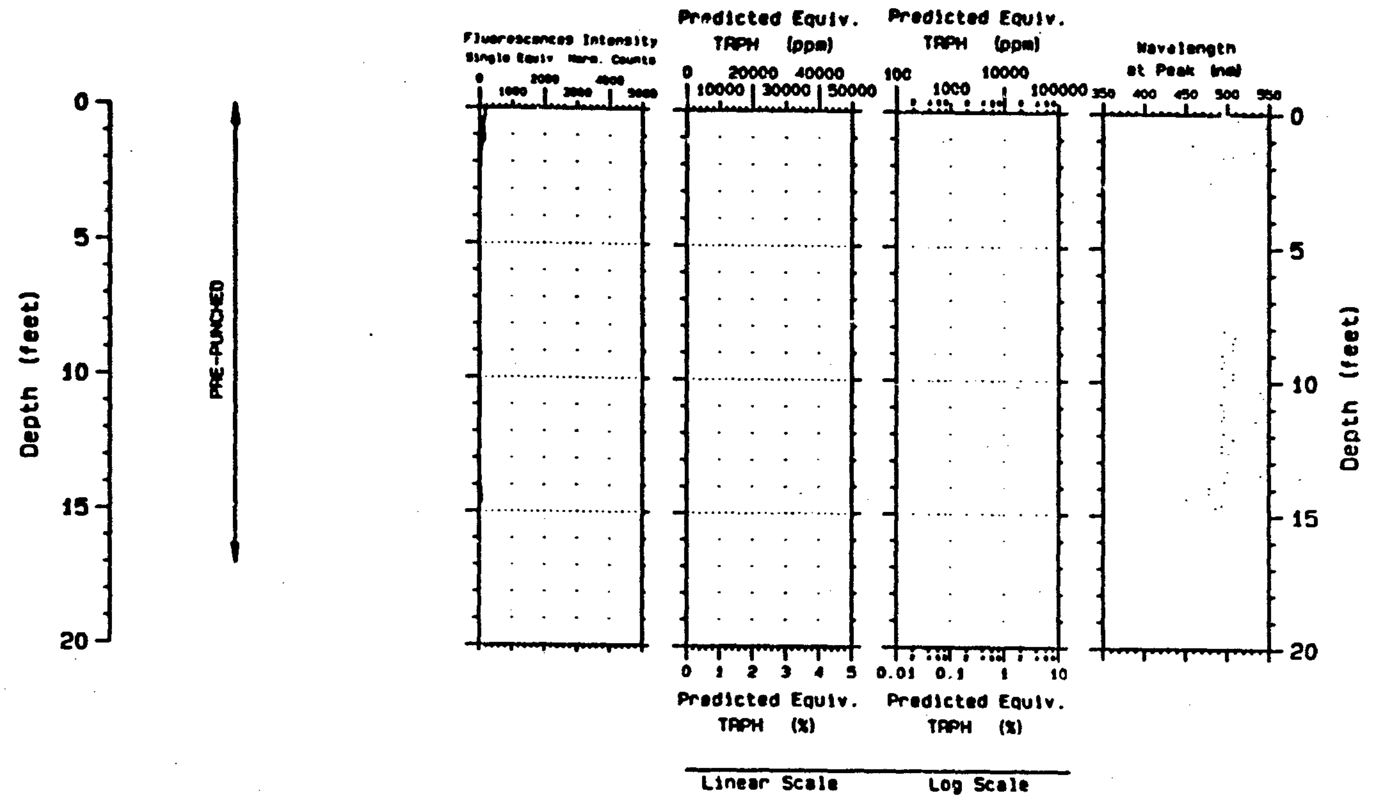
CPT: CP-RW-02 Project: Philadelphia Naval Shipyard

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)
2728174	212859

1 foot = 0.3048 meters
1 ton/ft^2 = 0.958 bars

Figure 73. Results of probe 2 at the Runway site.



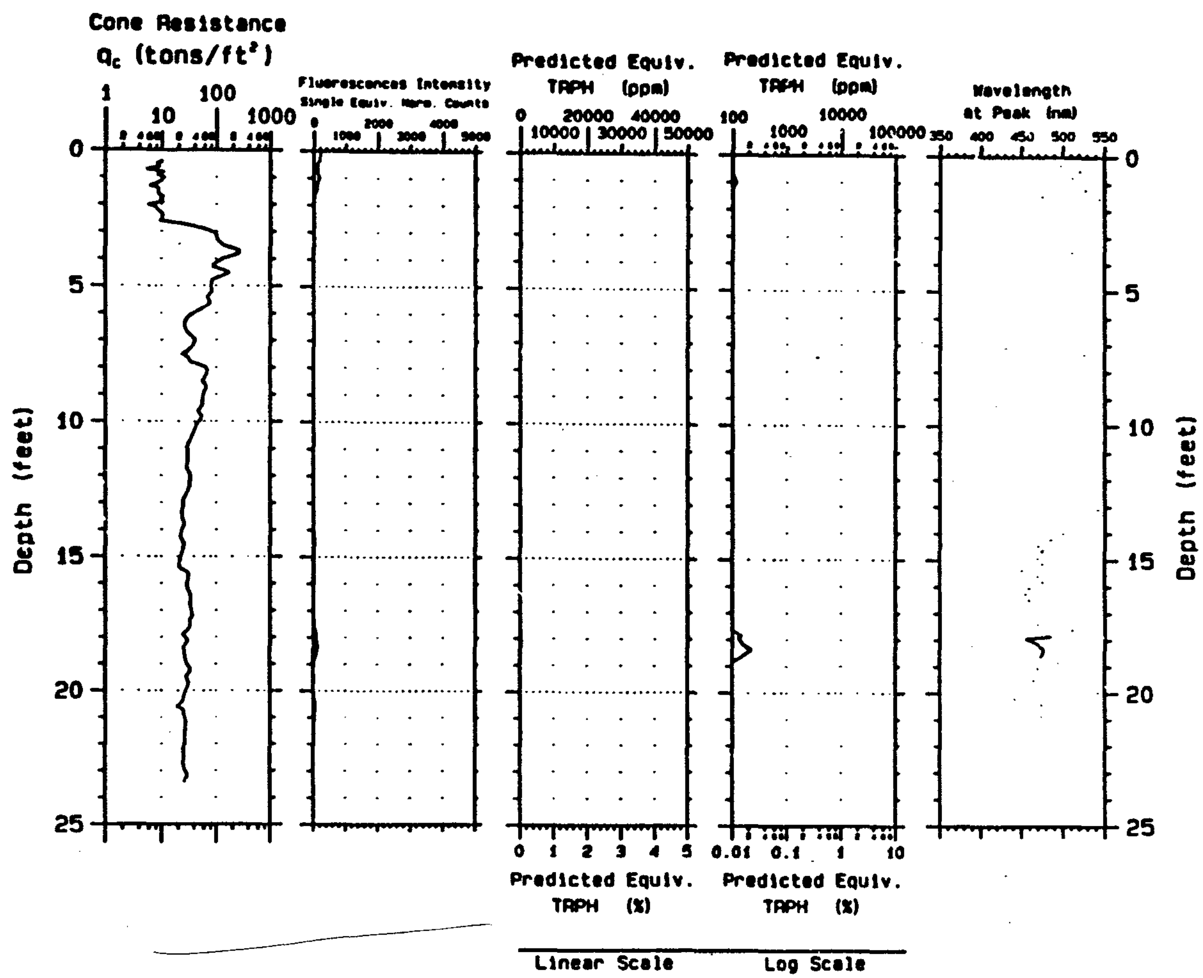
CPT: CP-RW-03 Project: Philadelphia Naval Shipyard

STATE COORDINATES:

EASTING (ft.) 272833; NORTHING (ft.) 212877

1 foot = 0.3048 meters
1 ton/ft² = 0.958 bars

Figure 74. Results of probe 3 at the Runway site.



CPT: CP-RW-04 Project: Philadelphia Naval Shipyard

STATE COORDINATES:

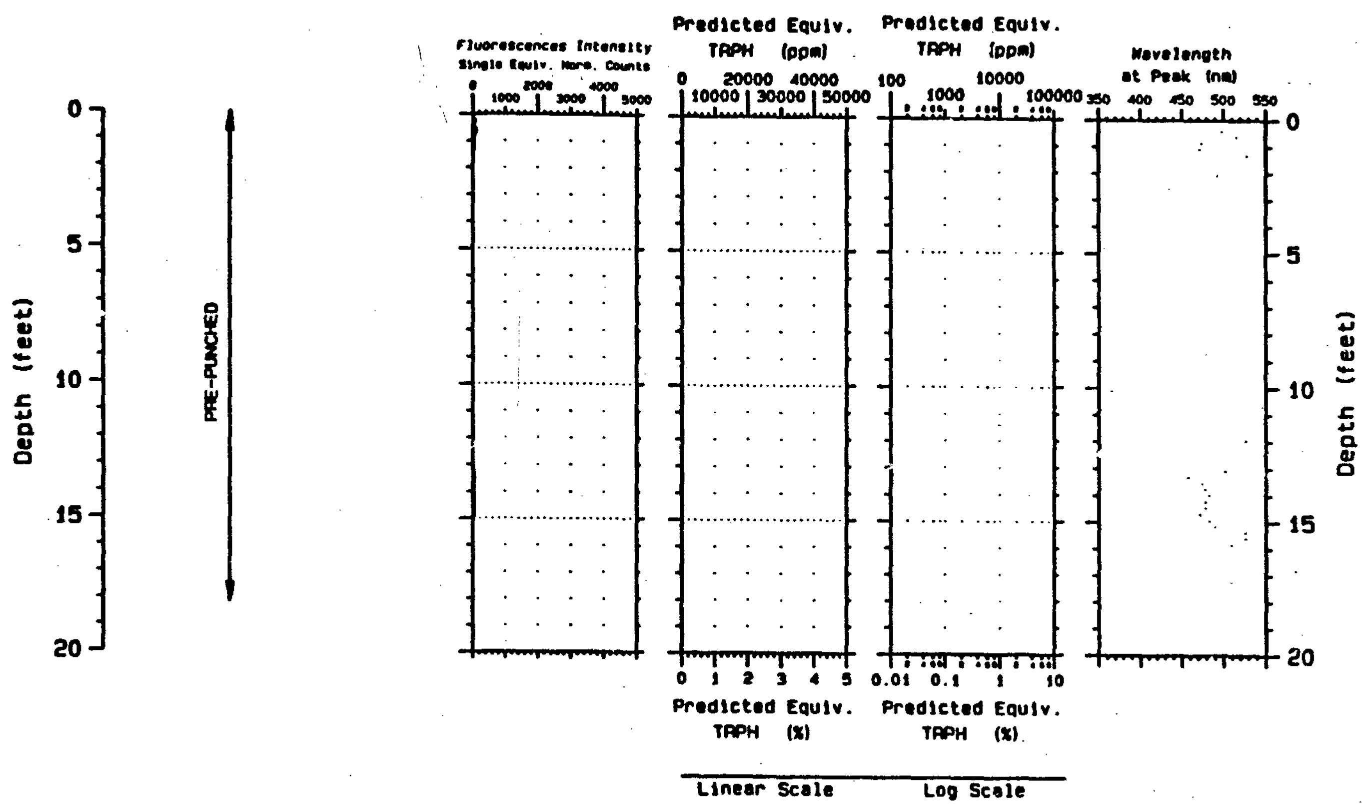
EASTING (ft.) NORTHING (ft.)

2728370 212881

1 foot = 0.3048 meters

1 ton/ft² = 0.958 bars

Figure 75. Results of probe 4 at the Runway site.



CPT: CP-RW-05 Project: Philadelphia Naval Shipyard

STATE COORDINATES:

EASTING (ft.) NORTHING (ft.)

2728278 212806

1 foot = 0.3048 meters

1 ton/ft^2 = 0.958 bars

Figure 76. Results of probe 5 at the Runway site.

Push four also shows a small hit at a depth of 18 ft at which point the probe was continued for another three feet (21 ft total depth). Push five did not show anything above minimum system threshold.

Table 6. Summary of results for the Runway site.

PROBE NAME	DEPTH INVESTIGATED (FROM GROUND SURFACE)	PRODUCT ENCOUNTERED	POSSIBLE PRODUCT
CP-RW-01	0 - 18 ft	no	NA
CP-RW-02	0 - 18 ft	no	NA
CP-RW-03	0 - 18 ft	no	NA
CP-RW-04	0 - 21 ft	yes; 18 ft	?
CP-RW-05	0 - 18 ft	no	NA

55. The three dimensional representation of data from this site is shown in Figure 77. The Figure shows very small patches of data that are probably attributable to noise in the system.

PNSY
RUNWAY SITE

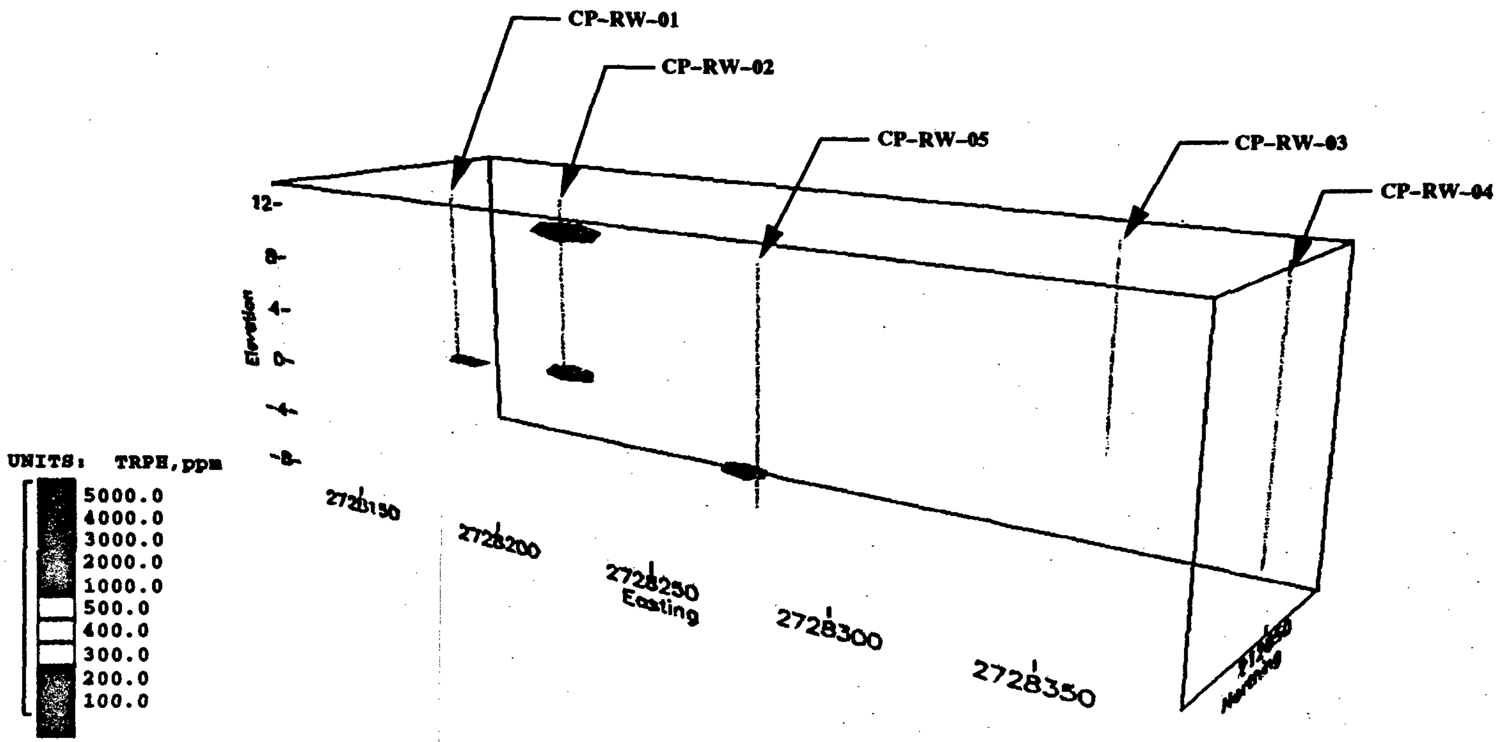


Figure 77. Volumetric representation of Runway results showing TRPH

PART V: CONCLUSIONS

56. Considering the data that was collected at each site, it appears as though more probes would have helped in the analysis of the plume presence and extent. However, time and in most cases physical constraints did not allow more probes to be pushed. Still, the data that were collected presents a very clear picture of the presence or absence of contaminants in the areas investigated. The vertical extent is clearly defined for each plume encountered.

57. A brief discussion interpreting the results for each site follows. At the Wharf E site, the contaminants appear to be contained within the excavated pit area. None of the probes outside the pit encountered any counts that would be considered significant. Inside the pit, the product appears to be confined to the south end, which could have been more confidently displayed with further probes. The product also appears to be confined to the top 8 ft, since 5 ft has already been removed, the removal of an additional 3.5 ft would safely eliminate all product in the subsurface.

58. At the Wharf G site, the contaminant plume is associated with the three underground storage tanks. The plume appears to be spreading to the south and west along the water table. There is no indication that the plume is moving north, however additional probes would need to be pushed to confirm this view. The counts in this area were quite high, revealing the presence of considerable product in the ground. The plume has already reached a depth in some areas of 15 ft.

59. The DRMO site contains a contaminant plume associated with the oil water separator. The plume appears to be spread from the oil water separator in a southwesterly direction. The counts encountered in probes 1, 3, and 4 would indicate that the plume is not as concentrated as those in probe 2 (directly across from the oil water separator). This could mark the boundary of the plume, which could be confirmed with more probes. The plume is contained between a depth of 3 and 7 ft, possibly sitting on the water table.

60. The material encountered at the crane shop (south of building 753) is associated with a tank that was removed. The plume is sitting at a depth of approximately 10 ft. When the tank was removed this material might have been contaminated, or possibly the material was already contaminated and not enough excavation was performed. In either case, the contamination appears to be localized to this area. From the probes conducted northwest of building 753, only small patches of material was encountered. There may be a plume at this site near the east end of the push area at a depth of 10 to 13 ft.

61. The NAVSSES site undoubtedly has a plume located around the storage tanks. Physical constraints at the site did not allow very many probes in this area to determine the lateral extent of the plume. Product was encountered from just below the ground surface to a depth of 5 ft. It is not unreasonable to believe that the entire tank storage area may be contaminated.

62. At the runway site, there is no indication that a hydrocarbon contaminant plume exists. The underground storage tanks at the site are believed to contain sand blasting grit residue, which would not fluoresce.

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